MITIGASI DAN ADAPTASI PERUBAHAN IKLIM

DARI ITS UNTUK BANGSA

Pulau Muncul

Gundukan Lumpur/lempung diantara pasir dan gravel

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Labuhan

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PUSAT STUDI KEBUMIAN BENCANA DAN PERUBAHAN IKLIM (PSKBPI)
LEMBAGA PENELITIAN DAN PENGABDIAN KEPADA MASYARAKAT (LPPM)
INSTITUT TEKNOLOGI SEPULUH NOPEMBER (ITS)

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Mitigasi dan Adaptasi Perubahan Iklim
Dari ITS Untuk Bangsa

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SEKAPUR SIRIH

Puji syukur kami panjatkan ke hadirat Tuhan Yang Maha Esa atas terbitnya buku “Mitigasi dan Adaptasi Perubahan Iklim dari ITS Untuk Bangsa” ini. Isu perubahan iklim dan pemanasan global merupakan isu strategis yang dampaknya sudah dirasakan di Indonesia. Berbagai fenomena perubahan curah hujan, perubahan suhu, kenaikan muka air laut dan cuaca ekstrim memberikan dampak buruk bagi kehidupan masa kini dan mendatang. Oleh karena itu, merupakan tantangan besar untuk menghasilkan terobosan-terobosan yang inovatif dalam upaya pengendalian/mitigasi serta adaptasi terhadap perubahan iklim. Buku ini menguraikan berbagai pemikiran akademik dan pengalaman praksis mengenai upaya-upaya mitigasi dan adaptasi terhadap perubahan iklim, antara lain upaya mitigasi terhadap peningkatan emisi gas rumah kaca (GRK), upaya adaptasi dan manajemen risiko perubahan iklim serta rekayasa teknologi bagi perubahan iklim.

Mitigasi perubahan iklim merupakan upaya pengendalian untuk mengurangi risiko akibat perubahan iklim melalui kegiatan yang dapat menurunkan emisi/ meningkatkan penyerapan GRK dari berbagai sumber emisi. Sedangkan adaptasi perubahan iklim merupakan penyesuaian pada sistem alam dan sistem kehidupan manusia dalam merespon resiko dan peluang yang timbul dari perubahan iklim. Melalui penyusunan buku ini diharapkan dapat memperkaya ide-ide/gagasan untuk solusi atau formulasi kebijakan peningkatan ketahanan suatu kota/wilayah dalam menghadapi perubahan iklim melalui upaya mitigasi dan adaptasi. Buku ini tersusun dari berbagai karya ilmiah yang merupakan hasil penelitian serta hasil diseminasi dan publikasi dari berbagai pertemuan ilmiah dan jurnal. Harapannya buku ini dapat bermanfaat bagi semua kalangan masyarakat, baik akademisi, birokrat, maupun praktisi.

Pusat Studi Kebumian Bencana dan Perubahan (PSKBPI) merupakan salah satu pusat studi Lembaga Penelitian dan Pengabdian Kepada Masyarakat (LPPM), Institut Teknologi Sepuluh Nopember Surabaya (ITS). Pusat ini dibentuk untuk menjalankan visi dan misi ITS dalam rangka berperan secara aktif dalam pengembangan ilmu pengetahuan, teknologi, dan seni, terutama di bidang kelautan, permukiman dan energi yang berwawasan lingkungan melalui kegiatan penelitian yang berkualitas internasional. Dengan memanfaatkan segala sumber daya yang dimiliki untuk ikut serta dalam menyelesaikan problem-problem yang dihadapi oleh masyarakat.

Pusat studi ini terus berusaha membangun kesadaran dan kepedulian terhadap bencana, khususnya civitas ITS dan umumnya masyarakat di Surabaya dan Jawa Timur. Bersamaan dengan itu, kita juga membangun jejaring dengan berbagai pemangku kepentingan yang bergerak di bidang kebumian, bencana, dan perubahan iklim baik nasional, regional ataupun internasional. Beberapa jejaring yang menjadi partner PSKBPI, antara lain : Gubernur Jawa Timur, BNPB, BPBD Jawa Timur, BPBD Kabupaten/Kota di provinsi Jawa Timur, Satkorlak PB Kota Surabaya, PVMBG Badan Geologi, MPBI, Forum PT PRB, UNICEF, UNDP, UN OCHA, UNEP, UNDAC, SCDRR, AUSAID, USAID, OXFAM, GTZ, Paklim GIZ, LSM, dan masyarakat.

Pada kesempatan ini, ucapan terimakasih yang sebesar-besarnya disampaikan kepada Lembaga Penelitian dan Pengabdian Kepada Masyarakat (LPPM) ITS, Pusat Studi Kebumian, Bencana dan Perubahan Iklim (PSKBPI) ITS, Komunitas Mahasiswa Mahagana ITS, serta pihak-pihak tekait yang mendukung penerbitan buku ini. Kami terbuka untuk segala diskusi dan masukan yang membangun penyempurnaan buku ini.

Rektor ITS

Prof. Ir. Joni Hermana,MScES.,Ph.D.

Mitigasi dan Adaptasi Perubahan Iklim
Dari ITS Untuk Bangsa

HANTARAN

1. **Mitigasi Perubahan Iklim**
   - **Bagian 1. Pengurangan Emisi** memberikan upaya-upaya pengurangan emisi dalam mengurangi risiko perubahan iklim. Pengurangan emisi bersumber dari gedung dan transportasi menjadi fokus beberapa *paper* dalam buku ini.

   - **Bagian 2. Ketahanan Air** memaparkan penilaian terhadap kualitas dan kuantitas air tanah dan penentuan upaya adaptasi terhadap kekeringan.

2. **Adaptasi Perubahan Iklim Untuk Pengurangan Risiko**
   - **Bagian 1. Fenomena Kenaikan Muka Air Laut** menjelaskan dampak kenaikan muka air laut terhadap perubahan garis pantai, kualitas air tanah dan perkiraan fenomena tersebut dimasa depan. Dalam pengurangan risiko perubahan iklim melalui fenomena ini, buku ini menjelaskan proses penentuan faktor kerentanan dan upaya-upaya pengurangan risiko.

   - **Bagian 2. Fenomena Perubahan Curah Hujan** menjelaskan proses peramalan curah hujan, penilaian terhadap banjir dan faktor dalam membangun ketahanan masyarakat terhadap banjir.

   - **Bagian 3. Manajemen Risiko Perubahan Iklim** memaparkan berbagai langkah-langkah dalam pengurangan risiko perubahan iklim.

3. **Rekayasa Teknologi Dalam Perubahan Iklim** menjelaskan berbagai instrumen teknologi yang dapat dimanfaatkan dalam pengurangan risiko perubahan iklim

Mitigasi dan Adaptasi Perubahan Iklim

Dari ITS Untuk Bangsa

DAFTAR ISI

Mitigasi Perubahan Iklim **Halaman**

Reducing Energy Consumption through Innovative Glass Layering Construction with Polyethylene Bubble Wrap at 2nd Floor Dean Faculty Room

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Abstract – *Reducing energy consumption in buildings has been an important and growing concern in most countries since the Kyoto Protocol was entered into force in 2005. For instance, ITS has set the target reduction of greenhouse gases in building and support act as a legal framework for promoting ECO Campus program. Design concept using glass layering construction with bubble wrap can contribute significantly in reducing the required air conditioning system size so annual energy cost decrease too. The objective of this paper is to present an overview of the basic principles of thermal insulation, the example of building energy modeling using polyethylene insulation materials, and to survey the most commonly used building insulation materials as well as their performance characteristics. A "bubble wrap" with a reflective insulation helps to reduce heat loss by reflecting away up to 97% radiant energy with less than 0.05 emittance. The result from this study is 3% to 6% annual energy savings was cited.*

Keywords: *reducing energy consumption, glass construction, bubbles wrap*

Introduction

Since the Kyoto Protocol was entered into force in 2005, reducing energy consumption in buildings has been an important and growing concern in most countries. The Indonesian government has set the target reduction of greenhouse gases in buildings and has promulgated the "Green Building Construction Support Act" as a legal framework for promoting green buildings. This is presumably due to the frequent hotter and colder days resulted from abnormal climate change as well as the increasing number of large-scale buildings with high energy consumption.

The use of thermal insulation is regarded as one of the most effective means of energy conservation in buildings. The thermal resistance offered by an insulation layer increases with increasing layer thickness and decreasing thermal conductivity. The R-values used to design building structures depend strongly on the thermal conductivity of insulation materials which relies on the density, porosity, moisture content, and mean temperature difference of the material [1].

The relationship between the temperature and the thermal conductivity of various insulation materials (fiberglass, wood wool, mineral wool, rock wool, polyethylene, polyurethane, and polystyrene) was investigated by Abdou and Budaiwi [2]. They concluded that thermal conductivity varied with operating temperature for all tested materials and that a larger temperature gradient resulted in higher thermal conductivity. Polyurethane and polystyrene had the lowest rate of change in thermal conductivity while polyethylene had much greater rates of change. Another study that considered by Al-Khawaja [3]. The total costs among three different insulation materials (wall mate, fiberglass and polyethylene foam) for light-colored and deep-colored surfaces were compared.

The objective of this paper is to observed an overview and behavior of glass layering constructions at 2nd floor dean faculty room using polyethylene insulation materials to layer some of the glasses are exposed to the greatest sun's heat, the influence to the saving capacity of air conditioning and effectiveness to annual energy saving.

Peer-review under responsibility of the Cities International Seminar Committee.

Material and Methods

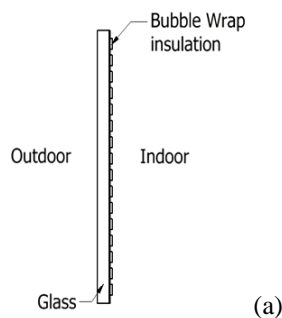
The reducing energy consumption could be achieved by proper insulation material. The choice of the proper insulation materials type and form depends on the type of application as well as the desired physical, thermal materials and other properties. Because most thermal insulation materials exhibit heat flows by conduction, radiation, and convection resulting in property variation with material thickness, or surface emittance, the premise of a pure conduction mode is not valid, therefore, the term apparent is implicit in the term thermal conductivity of insulating materials [4]. The bubble wrap layer or layers provide both thermal conduction and convection insulation and, in combination with the conductive/reflective surface, excellent radiation insulation (Table 1).

Table 1

Parameter of polyethylene insulation materials [4]

Parameter	Characteristics
Form	Blankets: Batts or Rolls
Density	35-40 Kg/m^3
Thermal conductivity	0.041 W/m-K
Coefficient of thermal expansion	100-200 x 10^{-4} K^{-1}
Specific heat	1900-2300 J K^{-1} Kg^{-1}
Effect as vapor barrier (% water absorption)	Good
Effect as infiltration barrier	Good
Resistance to direct sunlight	Good
Maximum service temperature	-40-90^o
Cost per *R*-value	Low

The bubble wrap has a first thermoplastic film having a plurality of portions wherein each of said portions defines a cavity (Fig. 1a and b) and a second thermoplastic layer in sealed engagement with said first layer to provide a plurality of closed cavities.

Energy saving from the second law of thermodynamics (Eq. 1-3), it is known that there must be a temperature difference between the surface and the surroundings or ambient if there is heat transfer (Fig. 1c), the heat transfer will include conduction, radiation and convection.

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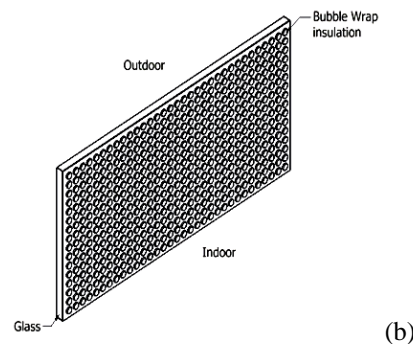
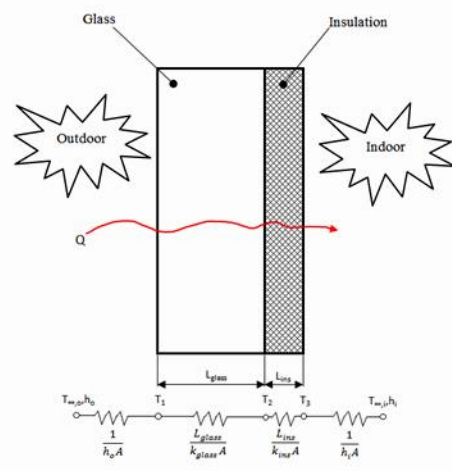

(b)

(c)

Figure 1. Described the concept of glass layering construction of bubble wrap (a) glass rear view (b) glass isometric view and (c) Equivalent thermal circuits for a window with insulation.

$$q = h(Ta - Tw) \quad (1)$$

Q passes through each layer on the window, solution at the surface becomes:

$$Q = UA(To - Ti) \quad (2)$$

Where U, the heat transfer coefficient is

$$U = \frac{1}{(1/ho.A) + (l_{gllas}/k_{glass}.A) + (l_{ins}/k_{ins}.A) + (1/hi.A)} \quad (3)$$

The study was conducted by collecting data about load each room in the 2nd level in the ITS head office building and calculating external and internal cooling load. Therefore, it can be determined whether the amount of air conditioning needed is sufficient or not. Furthermore, to reduce the capasity of air conditioner, bubble wrap polyethylene insulation materials is used to layer some of the glasses which are exposed to the greatest sun's heat. By doing this, the capacity of air conditioning can be reduced and it can save one since the heat from outside is inhibited to get inside so cold air in the room can be maintained.

Result and Discussion

The cooling load factor accounts for the storage of part of the solar heat gain. Values of Cooling Load factor to be applied to the solar heat gain calculation are shown in Table 2. The value is also dependent on whether or not there are internal shading devices.

Table 2

Correction factor cooling load for Single Glass external window

				U-value (Btu/hr.ft^2.F)
South	East	West	North	
0.58	0.62	0.15	0.8	1.01

Energy conservation amount of 2nd floor Dean Faculty Room can be calculated, and the contribution rates of energy conservation of them can be further analyzed (see Fig. 2a), from one, it can be seen that the retrofit of external windows is the most efficient, followed by the retrofit of external floor.

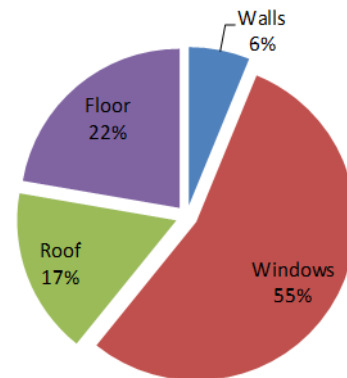
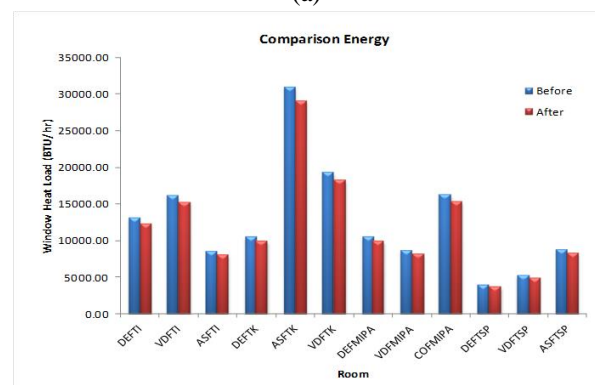
One of the strategies to reduce energy consumption is using glass layer with PE bubble wrap. It can be seen that the load of building envelopes greatly changes before and after layering bubble wrap insulation (Fig. 2b). Glass insulation is the most cost-effective measures for building improvement (see Table 3).

(a)

(b)

Figure 2. (a) The energy conservation contribution of envelopes retrofit of 2nd floor Dean Room (b) Comparison between energy before and after insulation in window.

However, it should be noted that the calculations of energy use and saving are based on the only in 2nd floor. Nevertheless, draught proofing appears to be the best option in terms of disruptiveness and cost effectiveness. The proportion of window load reduces from 13042 Btu/hr to 12283 Btu/hr for Dean Faculty of Industrial Technology room. The total of cooling load in this room for external wall, window, floor and roof is 35628.55 Btu/hr and then after insulation decrease to 34869.72 Btu/hr. The main reasons for those changes are the adding of ks or coefficient conduction by insulation so cause increasing u-value and drop cooling load from window about 5.82%. Its contribution proportion to total cooling load is also decrease cause of layering bubble wrap insulation.

Table 3
Modelled energy use and energy saving following glass insulation for 2nd floor Dean Faculty Room

Room	Q window (Btu/hr)		Energy Use (Btu/hr)		Energy saving	
	Before insulation	After insulation	Before insulation	After insulation	Btu/hr	% change
Dean Faculty of Industrial Technology	13042.72	12283.90	35628.55	34869.72	758.83	5.82
Vice Dean Faculty of Industrial Technology	16095.41	15158.98	34503.91	33567.47	936.43	5.82
Academic Staff	8508.19	8013.18	32163.30	31668.29	495.01	5.82
Dean Faculty of Marine Technology	10466.08	9857.16	25255.66	24646.74	608.92	5.82
Academic Staff	30880.63	29083.99	55765.42	53968.79	1796.63	5.82
Vice Dean Faculty of Marine Technology	19316.75	18192.90	38483.96	37360.11	1123.85	5.82
Dean Faculty of Mathematics & Science	10466.08	9857.16	27730.95	27122.03	608.92	5.82
Vice Dean Faculty of Mathematics & Science	8654.31	8150.80	19598.53	19095.03	503.51	5.82
Conference	16238.28	15293.54	40462.64	39517.89	944.74	5.82
Dean Faculty of Civil and Planner Eng.	3906.76	3679.47	21107.54	20880.25	227.30	5.82
Vice Dean Faculty of Civil and Planner Eng.	5232.87	4928.42	21222.52	20918.07	304.45	5.82
Academic Staff	8794.79	8283.11	31654.47	31142.79	511.68	5.82
TOTAL	151602.86	142782.6	383577.44	374757.19	8820.25	-

According table, energy conservation amount of building envelopes can calculated, and contribution rates of energy conservation of them can be further analyzed. From this it can be seen that retrofit of glass insulation is the most efficient.

Conclusion

This paper analyzed the insulation benefits and cooling load reductions achieved by introducing optimum layer insulation of bubble wrap selected materials in the window of Dean Faculty room in Institut Teknologi Sepuluh Nopember, Surabaya. Cooling load reductions were calculated using energy consumption caused by heat transfer through the room window. The paper showed that bubble wrap can reduce cooling load about 5.82% and with selected insulation materials can reduce load of air conditioned buildings. Hence, this study will be a good guide for the developers to introduce insulation material which cheaper and mostly available to reach. With a proper insulating material installed at its optimum insulation cannot only reduce the heat transfer through building's window but also has economical and environmental advantages that should not be ignored.

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IImproved Energy Saving for R22 Building Air Conditioning Retrofitted with Hydrocarbon Refrigerant, Study Case : Civil Engineering Department of ITS

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Abstract – *Sepuluh November Institute of Technology (ITS) encourages the ECO Campus program. The program enables ITS to systematically identify, evaluate, manage and improve their environmental performance and practices. One of the program issue is energy saving in building. The energy saving effect of an air-conditioning system retrofit project is analyzed by Energy Conservation Opportunities (ECOs) Method. These ECOs are assessed in terms of their costs and benefits, and an economic comparison to rank the various refrigerants. Finally, an Action Plan is created where certain ECOs are selected for implementation. Civil Engineering Department has a responsibility to design infrastructure and green building concept planning. This department also has the largest energy consumption in this faculty comparing the other department. The energy consumption on this Department is 60829 kWh/month. The value of IKE is 13.39 per month with the largest electrical energy consumption in air-conditioning system is 57% from total consumption. The energy used of air-conditioning sytem is 523.692 kWh. The energy saving opportunities by CFC retrofitting with hydrocarbon can save its power consumption about 20%. It also saving cost and reducing the electricity bill of 1643871.838 IDR/month. The payback period of investment costs of retrofit R-22 to Hydrocarbonis about 13 month.*

Keywords: *global warming, Civil Engineering Department, retrofit, energy consumption opportunities*

I. INTRODUCTION

Global warming is the increasing of the world‘s temperatures, which causes in melting of the polar ice caps and rising sea levels. It is caused by the release of CFC gases into the atmosphere [1]. The Montreal Protocol, an international environtmental agreement, established requirements that began the worldwide phase out of ozone-depleting chlorofluorocarbons (CFCs). These requirements were later modified. This led to the phase out, in 1996, of CFC production in all developed nations. In 1992 an amandment to the Montreal Protocol established a schedule for the phase out refrigerants, hydrochlorofluorocarbons (HCFCs)[2].

An HCFC, known as R-22, has been familiar for residential heat pump and air-conditioning systems for more than four decades. Unfortunately for the environtment, releases of R-22 that caused by system leaks contribute to ozone depletion. As R-22 is phased out over the coming years as part of the agreement to end production of HCFCs, manufacturer of residential air-conditioning systems are beginning to offer equipment that use ozone-friendly refrigerant [2].

The Air Conditioning appliances which are commonly sold in the market is entered and also used in many institution such as ITS. This campus encourages a program called ITS ECO Campus. Eco campus is activities that systematically identify, evaluate, manage and improve their environmental performance and practices to fight global warming due to excessive use of CFCs and environmental problem. The program is administered by the Coordinating Board Control and Communications Program (BKPKP) that has been implemented Eco Campus program, including the greening of the campus, saving water and waste management. But for saving electrical energy that is closely related to the using of Air Conditioning (AC) that is still not implemented in an integrated manner. The simple actions are often only change with larger or smaller appliances capacity

depending on which is needed. However, it will needhigh investment cost. Energy saving by replacing the refrigerant in AC appliances is still rarely done in ITS. Therefore, in order to accomplish ITS ECO energy saving program, the prediction of reduction in electrical energy consumption in which CFC retrofitted with Musicool-22 has been done.

Hydrocarbons however, are highly flammable and explosive, and their areable to use as refrigerant except in special applications and should be under the supervision of experienced operating personnel [3]. Because of their excellent thermal properties, the hydrocarbons are frequently employed in low temperature applications.

II. Methods

The work is started by collecting information about a facility's operation and its past record of utility bills. This data is then analyzed to get a picture of how the facility usages and possibility of energy waste and to provide nominated area for the auditor to examine. Specific changes-called Energy Conservation Opportunities (ECOs) are identified and evaluated to determine their benefits and their cost-effectiveness. These ECOs are assessed in terms of their costs and benefits, and an economic comparison is made to rank the various ECOs. Finally, an Action Plan is created in which certain ECOs are selected for implementation and the actual process of saving energy and saving money begins.

III. Result and Discussion

Overview of Faculty of Civil and Planning Technology, ITS Faculty Civil and Planning Technology has sufficient building for the implementation of a good quality teaching and learning process. A building has a floor area of 5254, 56 m2 and 4772, 3 m2 of laboratory. The number of student (Magister, Doctor, Bachelor, and Diploma) is about 4251 people and ratio building area to the lecturer room of 1, 27 m2 per student and laboratory 1, 16 m2 per student. This faculty is the oldest department in the ITS region and has a land area covering and gross area of 4541, 5 m2. The expansive building covers an area of, I, J, and E building.

Occupancy Rate

Occupancy rate is taken based on secondary data and primary data from the Department of facilities and infrastructure ITS Surabaya. Occupancy rate can be seen in table below

Table 1.Occupancy Rate in Faculty of Civil and Planning Engineering

Room	Gross Area (m^2)	occupation
I 101	93.81	85
I 102	93.81	85
I 103	93.81	78
Meeting Room	35.06	14
A Large lecturer room (4 room)	28.49	16
A small lecturer room (7 room)	13.29	7
J 101	93.81	70
J 102	93.81	70
J 103	93.81	85
A Large lecturer room J (4 room)	28.49	16
A Large lecturer room J (3room)	28.49	12
E 101	119.72	140
E 102	119.72	140
Administration S2	117.55	42
R Geo MPK	60.41	40
R MRSA Aset	60.88	35
R MAI	60.48	25
R MRT danStruktur	60.84	33

Source : Department facilities and infrastructure ITS Surabaya

Table 2.Data Temperature, Humidity, and Light Intensity

Room	T_{db} (°C)	RH (%)	Lux
I 101	28.87	54.22	348.5
I 102	27.5	54.47	318
I 103	27.25	56.72	243.25
Meeting Room	29.67	71.82	489.5
A Large lecturer room (4 room)	29.3	71.85	247
A small lecturer room (7 room)	29	68.6	184
J 101	27.4	43.7	299.25
J 102	27.1	54.55	274.75
J 103	28.6	53.12	369.5
A Large lecturer room J (4 room)	28.9	70.85	172
A Large lecturer room J (3room)	27.6	54.23	350.25

E 101	27.9	55.92	351.25
E 102	30	52.2	172
Administratif S2	27.62	48.35	210.75
Geo MPK Room	28.32	49.0	256.5
R MRSA Aset	28.4	56,7	267,7
R MAI	28.4	60.5	474.67
R MRT dan Struktur	28.95	58.57	279

Energy Consumption

The temperature and relative humidity measurement has been done in lecturer building and administrative building. Those buildings are selected for due to have a high opportunity of energy conservation. Table 2 shows the temperatures, humidity, and light intensities data in the building. The electrical energy cost is obtained from the electrical energy consumption data of Civil Engineering Department of ITS Surabaya within a period of four years (the period January 2009 – December 2012).
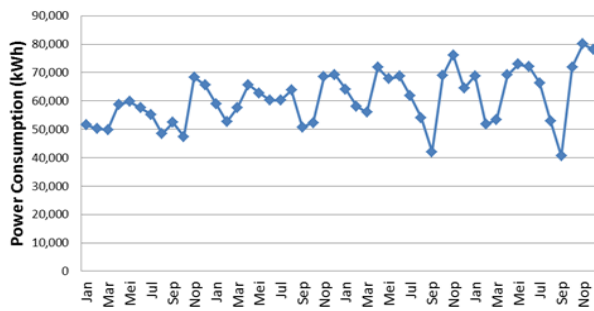
Fig 1. shows the electrical consumption in Civil Engineering Department. The figure informs us that the electrical energy consumption is a slightly high.

The electrical consumptionis increasing in every year because of power consumption increases due to intensifying of equipments usage and growing of student number. In the months of February until April and October until November each year the electric power consumption has increased. This is because in these months, student learning activities effectively increases and also they did a lot of lab work. However, in June-August and January-February electricity consumption has sharply decreased since semester holiday. The electric power consumptionis an average of about 60829 kWh/month.

Energy Consumption Intensity (IKE)

Energy consumption intensity is the amount of energy usage per gross building square meters in a time series. Gross complex area of Civil Engineering Department is about 4541.5 m2 withan averages electrical energy consumption on Civil Engineering Department is of 60829 kWh, so the IKE is of 13.39 per month.
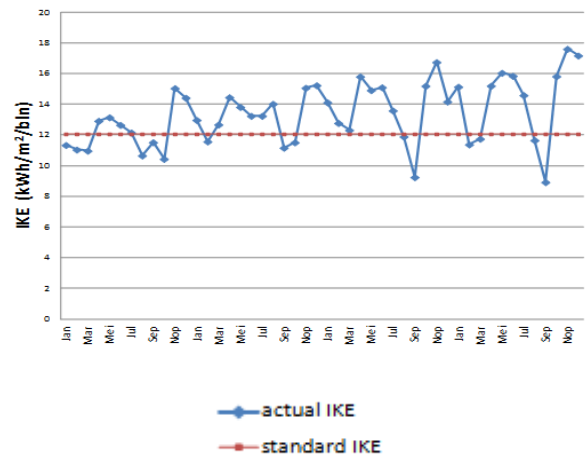
Fig 2.Graph IKE (kWh/m2) Civil Engineering Department, ITS

Fig. 2 above shows that the value of IKE in Civil Engineering Department which get from 4 years later is not efficient, only a few month of these year is efficient and the other is spendthrift. The efficient room standard is based on Energy Conservation Guidance in DEPDIKNAS which is divided in two criteria, air-conditioning room and non conditional room. The standard value is called efficient if the IKE values are in range 7.93 – 12.08 [4].

Energy Conservation Opportunities Estimation

Electrical energy consumption in Civil Engineering Department is definedsuch as lighting, air-conditioning, and appliances electrical consumption. Here is diagram electrical energy consumption in this Department pie diagram.

Fig 3.Profile Electrical Energy Consumption Civil Engineering Department, ITS

The diagram shows that the largest electrical energy consumption is air-conditioning appliances with 57% of total electrical energy consumption and the energy consumption of air-conditioning is of 523.692 kWh. So that,it can encourage an energy conservation program in air-conditioning system which have the largest electrical energy consumption in this Department. First task is to find the refrigerant which suitable with the specification of R-22 in each air-conditioning appliance installed in Civil Engineering Department. Table3 below shows the value of ODP, GWP in many refrigerant references to do the conservation opportunities by retrofit R-22 to R-290 as known hydrocarbon. This action can save electrical energy of14% to 20% with cooling temperature is better [5].

Table 3.Normal Boiling Point (oC), ODP and GWP many Refrigerant [1,6]

Refrigeran	Tipe	ODP	GWP	NBP
R12	CFC	1	8500	-29.8
R13	CFC	1	14000	-81.4
R22	HCFC	0,07	1700	-41
R23	HFC	0	11700	-82
R170	HC	0	3	-
R290	HC	0	3	-42
R404A	HFC	0	3260	-47
R744	N	0	1	-57

The substitute of R-22 with Musicool-22 isgiving more electrical energy consumption saving and cooler because a Musicool-22 thermodynamics property is better that of R-22, as shown in table below. From this table is shown that Musicool-22 has a refrigeration effect much better and it uses smaller compression work than that of R-22. Therefore, it is very advantageous to retrofit refrigerant R-22 with hydrocarbon refrigerant (Musicool-22) to save energy cost.

Table 4.Comparison physics and thermodynamics characteristics of Musicool-22 & R-2

NO	PARAMETER	Musicool-22	R-22
1	Saturated liquid at 37,8^{o} C, Kj/Kg	2,909	1,325
2	Saturated vapor at 37,8^{o} C, Kj/Kg	2,238	0,9736
3	Thermal conductivity of saturated liquid at 37,8^{o} C, w/m	0,0868	0,0778
4	Thermal conductivity of saturated vapor at 37,8^{o} C, w/m	0,0211	0,0128
5	Saturated liquid density at 37,8^{o} C, (kg/m^3)	28,53	62,46
6	Saturated vapor density at 37,8^{o} C, (kg/m^3)	2,412	4,705
7	Saturated liquid viscosity at 37,8^{o} C, (uPa-s)	84,58	143,10
8	Saturated vapor viscosity at 37,8^{o} C, (uPa-s)	9,263	13,39

Estimation energy conservation opportunities by retrofits R-22 to Musicool-22 in Civil Engineering Department as follow:

Table 5.Estimation cost profit

Electrical Energy Saving		
Unit AC	96 unit	96 PK
Average Electricity Power Before Retrofit	2.3804 Amp	523.692 Watt
Average Electricity Power After Retrofit	1.9043 Amp	418.954 Watt
Total Energy Saving	0.4760 Amp	104.738 Watt
Ratio Energy Saving	20 %	

Simple Payback Period Method

Total saving cost if implementation energy conservation opportunities (ECO) with retrofit R-22 to Musicool-22 is 250.000 IDR per unit AC. Time to breakeven point infestations can calculate with:

$$SPB = \frac{\text{Infestation Retrofit R22 to MC22}}{\text{Conservation Opportunities (Month)}}$$

$$SPB = \frac{21000000}{1643871.838}$$

$$SPB = 13 \text{ month}$$

So infestation costs to retrofit R-22 to Musicool-22 can payback in 13 month.

Refrigerant	Basic Electric Cost (IDR)	Power consumption (kWh)	KVARH	Cost/day (IDR)	Cost/month (IDR)	Cost/year (IDR)
R-22	1013.00	523.692	324.555	328774.37	8219359.19	2465807757
Musicool-22	1013.00	418.954	259.644	263019.49	6575487.35	1972646205
Cost Saving					1643871.84	

Conclusion

Program energy saving can be succeeded by replacing R22 refrigerant with Hydrocarbon refrigerant and also it reduces the problem of global warming and ozone depletion. The using energy on Department Building is of 60829 kWh/month. The value IKE is of 13.39 per month with the largest electrical energy consumption is in air-conditioning appliances of 57% from total consumption. The estimation of energy saving opportunities by retrofitting it can save power consumption about 20%, and it’s also saving cost and reducing electricity bill of 1643871.838 IDR/month. The estimated investment costs of retrofitting R-22 with Musicool-22 can payback in 13 month.

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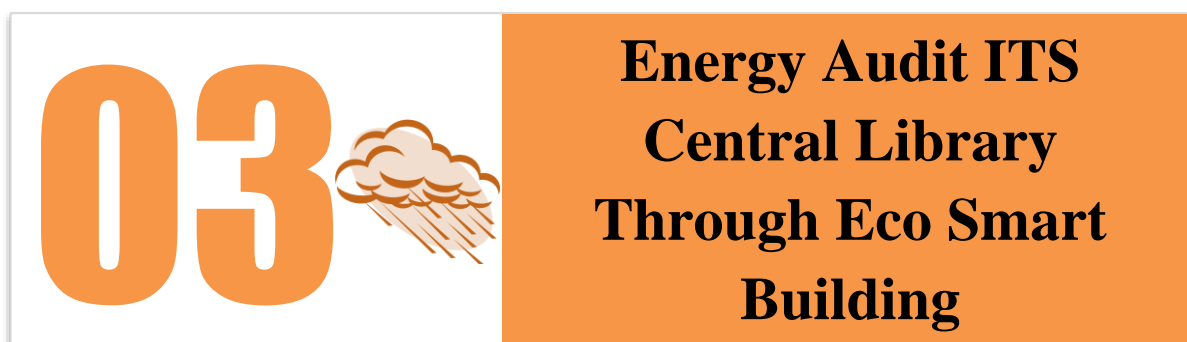
Energy Audit ITS Central Library Through Eco Smart Building

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Abstract – *Energy conservation is one of many technique applied to reduce the global warming effect. Sepuluh Nopember Institute of Technology (ITS) contributes to encourage energy conservation by ITS Eco Campus programs. It has so many activities, one of them is audit energy as one way to get energy efficiency in educational area. ITS central library is most accessable building both student and other academics community with total area more than 400 square meters and high occupation rate approximately 90% everyday. Energy audit techniques were carried out by an energy audit team to identify any energy conservation opportunities (ECOs). walk-through assessment and data analysis were conducted over all building zones. These levels of assessments proved that the building and its mechanical and electrical systems were improperly maintained and inefficiently operated. So that, ITS Central Library will be redesigned to be eco smart building by improving light intentensity level, humidity, and room temperature appropriate with ASHRAE 90.1-2005. Thus exterior building like wall, glass, roof and floor will be redesigned to emphasize minimum total load. Replacement single glass to double glass reduce the load conduction and radiation through glass, approximately 2,7%*

Keywords: *energy conservation, ITS central library, energy audit*

I. Introduction

Posisi Global warming is the rise in the average temperature of Earth's atmosphere and oceans since the late 19th century and its projected continuation. Since the early 20th century, Earth's mean surface temperature has increased by about 0.8 °C (1.4 °F). It is a problem which each of us contributes to because our everyday activities require the burning of fossil fuels which result in carbon dioxide (CO2) emissions, one of the major greenhouse gases that causes global warming. Nowdays, all of people try to reduce the global warming effect by themselves.

Eco campus program in various colleges include Sepuluh Nopember Institute of Technology (ITS) is one of programs to reduce the global warming effect. Eco Campus is defined as a campus that has applied the environmental culture and has been doing environmental management systematically and continuously. ITS has compiled environmental program 2011 to 2015. Eco Campus program encourages the creation of campus management policy oriented on environmental management, efforts to save water, paper and electricity, reforestation to achieve the ideal proportion of green open space (GOS), eco- buildings, maintained the cleanliness and comfort of the environment, and involvement of all elements of the academic community in the ITS culture of environmental care.

ITS central library is one of commercial building in ITS that most accessable both student and other academics commnity. It is a fun place to look for many different kinds of books. Walking through the library just opens up many kinds of opportunities to read and learn about many things. ITS central library is a place not only to get all kind of books but also become comfortable place to discuss and meeting.

ITS central library is a commercial building and located at central of Sepuluh Nopember Institute of Technology, Surabaya. This building was built in 1992. It consists of 6 floors. Each of division in every floor has many facilities such as reading room, café, wifi zone, internet room, magazine and reference room etc. This building also doesn’t have roof floor

for chillers and has lift installation. This building has total gross floor area of 7.500 m2 with occupation rate more than 90%. The operational hours of this building are normally between 08.00 to 18.00 from Monday to Friday and between 09.00 to 13.00 on Saturday.

But it also encourages the use of higher energy and making energy use to be one big contributor to the operational costs incurred. On the other hand, the world's energy reserves are running low. For that we need an energy conservation efforts for energy saving opportunities identification one of them at ITS central library building. ITS central library will be design as eco smart building that committed to reducing the energy consumption of built environment, commissioning the application of renewable and recycle energy systems.

An energy audit involves the systematic reviews of the energy consuming equipment in a building to identify Energy Management opportunities. Which provide useful information for the building owner to decide on and implement the energy saving measures for inveronmental consideration and economic benefits. This energy audit focused on 3rd and 5th floor of ITS central library. It has represented the usefull of energy consumption in ITS Central library because most of the other floors just as reservation areas.

II. Energy Audit Process

The Energy audit conducted in ITS Central library is a walkthrough audit. Since this type of audit is the simplest and least expensive kind of energy audit, the main scope is only to identify energy conservation opportunities based on basic information collected from the building management and basic observation on building condition, facility operation and daily habit and procedures in the building.

The walkthrough energy audit will be done in 2 workdays for survey and several days for analysis and reporting. At this stage, the building was assessed using several steps, namely:

1. Meeting and interview with building counterparts
   At this step, an initial meeting between auditors and key facility personnel will be held. At this meeting, key personnel of the building will introduce the building and its facilities to the auditors while auditors will explain the brief description of energy audit activities including all necessary documents needed to do the analysis
2. Document and data collecting
   At this step, the preliminary data should be taken including, building/factory characteristic, habits and procedure of daily operation, list of energy using equipment, electricity and other energy bill, marking/nameplate from equipment, logsheet or any recording data regarding to energy consumption.
3. Building survey and facility observation
   The building will be swept floor by floor (including roof and basement to observe utilities such as cooling towers and generators) to observe its condition in terms of lighting performances, thermal comfort, and room utilization. The other activities at this step are to observe energy supply system of the building, including main electricity meters and panels and fuel supply system and to observe major utilities in the building, such as chillers, boilers, heaters, and generators.
4. Document review and survey data analysis
   At this step, several documents collected from building counterpart will be reviewed and used as a basis to estimate the energy efficiency potential in the building. Meanwhile, the data collected from the observation were analyzed and used as reference for calculation.
5. Evaluation of energy conservation opportunities (ECOs)
   In this step, each opportunity that have been found in survey analysis will be evaluated to measure its effectiveness in the building energy conservation program
6. Economic analysis
   Economic analysis was conducted to further analyze the energy conservation opportunities in terms of payback period using simple payback period method.
7. Reporting and presentation
   Finally, the whole data will be written in a walkthrough energy audit report and will be presented. The expected output of the walkthrough audit is to identify the baseline energy consumption and the potential Energy Conservation Opportunities with recommendation to be analyzed further in the detailed audit.

III. Result and Discussion

III.I Building Envelope

The building envelope section presents analysis of practically existing building review base on the recent survey and using Cooling Load Temperature

Difference (CLTD method). The focus of this method is to calculate thermal accumulation in indoor environment affected by solar radiation and thermal conduction for each square meter of building.
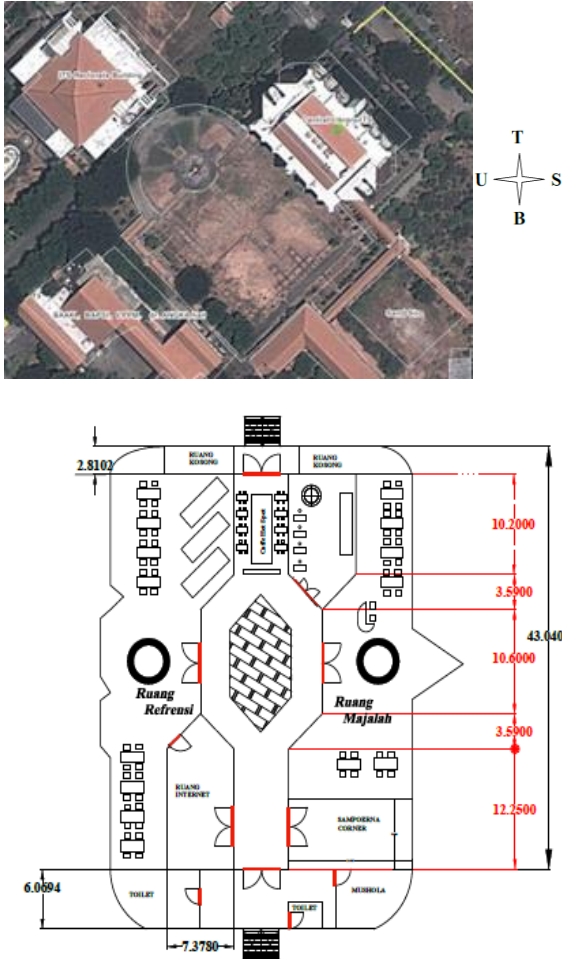
Figure 1.Central library of ITS (a) capture from satelit, (b) overall design in 3rd floor

III. I.I. Exterior Walls

The exterior walls of the original building are comprised of four courses of brick with a plaster finish on the interior. As is typical in this type of construction, the walls of the main building are uninsulated. No details of the existing building were available and no drawing references were found that would indicate insulation was added.

III. I.II Roof

According to the building maintenance staff, the main roof was installed in the late 1992s or early 1990s. Built-up roof assumed to have some rigid insulation in-place. The flat roof is at least 20 years old and has areas of ponding and soft spots. It requires patching on an annual basis. As evidenced on the walls, it has allowed moisture intrusion to the building. However, the flat roof is not serving as the thermal envelope in this building.

III.I.III Window

The main portion of the historic building has single-pane metallic windows throughout the façade. In some locations, the window openings were bricked over during the renovation. Replacement windows have been installed in some more concealed areas of the building. The windows require regular maintenance and are a significant source of air infiltration. Occupants report comfort issues related to the windows.

III.II Cooling Load

The room cooling load is the rate at which heat must be removed from the room air to maintain it at the design temperature and humidity. Cooling load has been classified into two types. It is external load and internal load. The cooling load consist of the following :

III.II.I External load

The external load is defined as load from outside that enter into inside such as conduction through exterior walls, roof, glass, interior partitions, ceilings, floors and Solar radiation through glass. The external load of ITS central library are specified in figure 2.
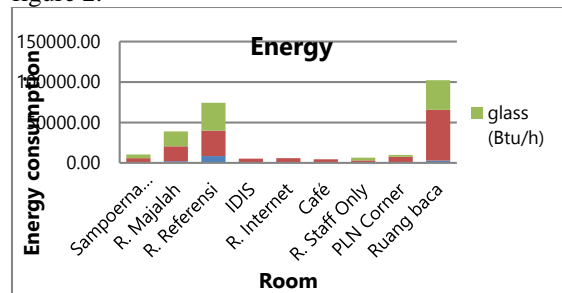
Figure 2.External load for conduction through wall, roof/floor, and glass

From chart in fig.2 we know that Reading room has the biggest cooling load through it glass, wall, floor and roof. It is more than 100.000 Btu/hr. However, at café in 3rd floor of ITS central library has the smallest value of cooling load, approximately 4465Btu/hr. This extreme value is so far because it has different design for different manner.

III.II.II Internal load

The internal load is load produced by the room include Lighting, People, Equipment and Heat from infiltration of outside air through Openings.

Table 6.Occupancy rate at ITS Central library

No	Room	T (C)	RH (%)	Lux
1	Sampoerna corner	26,7	41	226
2	R. Majalah	25,3	44	209
3	R. Referensi	25	53	205,8
4	IDIS	23	51,1	90,7
5	R. Internet	24,6	40	150,8
6	Café	26	45	70,6
7	R. Staff Only	28.98	62.38	372.5
8	PLN Corner	27	59.8	74.25
9	Ruang baca	28.6	63.84	254.3

Table 7.Temperature, Humidity and Light intensity Data

Table 1 show the occupancy rate at each room of ITS central library. Reading room is the largest area with high capacity until 190 people and produce 39225,5 Btu/h in load. In the other hand, Staff room is the narrowest place with low capacity 40 people and produce 8258 Btu/h in load. But it can't imagine the occupancion of each room. The occupation rate of each room is explained by ratio of area with occupation. Cafe at 3rd floor of ITS central library has the highest occupancy rate, 1.84 m^2 every person. And Reference room is the lowest occupancy rate place of ITS central library, approximately 10.07 m^2 per person.

III.III Comparison with ASHRAE 90.1 2005

The purpose of ASHRAE 90.1-2005 Energy Standard for Buildings to provide minimum requirements for the energy efficient design of buildings. ASHRAE Standard 90.1 applies to design and construction of new buildings and their systems, new portions of buildings and their systems, and new systems and equipment in existing buildings, where occupant comfort is the main concern rather than industrial, manufacturing, or commercial processes.

III.III.I Envelope

The ASHRAE Standard defines allowable maximum U-factors for exterior walls, roofs, and floors. It also defines minimum thermal resistance of slab-on-grade floors and below-grade walls, and maximum U factors and maximum shading coefficients for windows and skylights.

The data resulted from energy audit shows that heat transfer coefficient for walls is 0.65 W/m^{2}K, and for floor is 0.5 W/m^{2}K. Its value is lower than maximum value of requirement, 1.0 W/m^{2}K. Heat transfer coefficient for roof is 0.5 W/m^{2}K, also in ranging of requirement value, 0.7 W/m^{2}K.

Glass and windows on ITS central library have similar types and dimension each room. It is transparent single glass with 0.624x0.83 m^2 in small size and 0.83x1.90 m^2 in large size. The single glass type has U 1.01 Btu/h.ft^{2}F. So that, it has load 99657,61 Btu/hr. To reduce load from conduction and radiation through the glass we can replace single glass with double glass. It is because double glass type has lower overall heat transfer coefficient, 0.56 Btu/h.ft^{2}F and produce 96999,24 Btu/hr for load. We can conclude that replacement single glass to double glass reduce load from conduction and radiation through the glass, approximately 2.7%.

No	Room	Area (m^2)	Occupation
1	Sampoerna corner	96	15
2	R. Majalah	307.606	40
3	R. Referensi	523.773	52
4	IDIS	87.48	15
5	R. Internet	96.607	31
6	Café	73.95	40
7	R. Staff Only	38.8	10
8	PLN Corner	109.4	20
9	Reading Room	1047.548	190

III.III.II Lighting

The Standard references the existing national standard Lighting Design of Buildings for minimum requirements of interior lighting design. The exterior lighting is not covered by the Standard. Table 6 is a snapshot of maximum light intensity for education building

Table 8.Light Intensity requirement for educational building

Room	Light Intensity (lux)
Education	
Class Room	250
Library	300
Laboratory	500
Drawing Room	750
Cafetarian	200

Table 3 compares prescriptive requirements of interior lighting for some space types in the Standard. It can be seen that the light intensity requirement for library as part of educational building is 300 lux, has more stringent lighting requirements

than class room. Light Intensity as result of energy audit in ITS central library show in table 2. Most of room at that building have lower light intensity than the standard requirement for library. Its value is less than 300 lux. So it has not fulfill the requirement for comfortable condition both reading and writing. So that, to achieve the light intensity to the standard level of library, the number of efficient lamps must be added.

Additional gains can be achieved with a reduction of the cooling load by minimizing the internal gains from lights. In order the investigate the use of daylighting in the audited buildings, the necessary energy to artificially illuminate all the interior spaces of the buildings, at appropriate lighting levels, was calculated first. The lighting schedule and the type of lighting devices, in each building, was taken into account.

III.III.III Air Conditioning

The data collected by the author for each zone of the building on may, 2013 showed that the indoor air temperature is above the thermal comfort temperatures (24 ºC for summer and 22 ◦C for winter) most of the time in most of the building zones. Rectifying the situation will reduce the energy consumption of the building.

It can be observed from Table 2 that the temperature fluctuates between 23.0◦C and 28.9◦C as the minimum and maximum temperatures, respectively, for the 3^{rd} and 5^{th} floors of ITS Central library on may. This explains why most building users complained of over-heating in most areas of the building. This explained where the excess energy was not efficienct.

The temperature and relative humidity of some zones over the summer period are show in table 2 showing an indoor environment that is not within the recommended conditions. The hourly temperatures were above the recommended level during most of the summer period, ranging from 14 to 18◦C. The relative humidity ranged between 40 and 60%, which is in ranging the recommended level (30–60%). This clearly indicates energy use and explains the ucomfortable indoor environment.

In this study, the sensors had an accuracy of ± 0.4 ◦C at 25 ◦C; the accuracy of the relative humidity measurements was ±3.5% from 25% to 95%; and the light intensity was measured using sensors designed for general purpose indoor measurements with relative light levels that ranged from 1 to 3000 footcandle

IV. Conclusion

From this study we conclude that improving the energy efficiency of ITS central library buildings depends primarily on energy usage in educational buildings. Based on an energy audit experiences and the calculated energy consumption under several simulated interventions in the audited buildings, it appears that it is possible to reach energy conservation. This can be easily achieved by using alternative cooling systems such as replacement single glass to double glass to reduce load 2.7%, advanced fluorescent lighting using efficient lamp to fulfill light intensity requirement of library, 300 lux, and by improving the efficiency of the air conditioning system to get the standard comfortable temperature indoor in ITS central library, approximately 25ºC.

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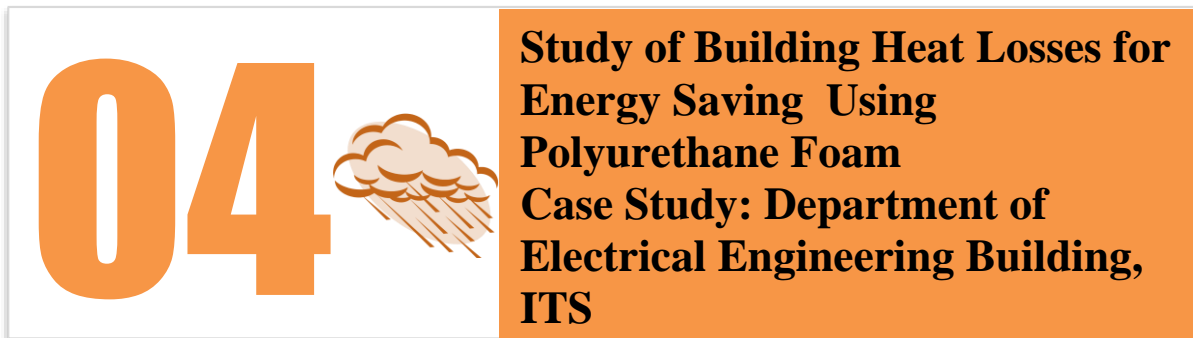
Study of Building Heat Losses for Energy Saving Using Polyurethane Foam Case Study: Department of Electrical Engineering Building, ITS

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Abstract – *It is important to save energy in a building. Saving energy can reduce cost and increase the efficiency of energy. Insulation building is one of the methods to decrease the heat losses.Insulation is aimed to minimize heat losses in a system. Insulation system can increase the energy utilization. Polyurethane (PU) foam is an interesting insulation material. It has low thermal conductivity (0.025 W/m.K). The low of thermal conductivitycan increase the thermal resistance and heat losses to the environment. This studyexamined the energy saving in the rooms withPU foam as the wall insulation on the surface. This study was done on the building of Departmentof Electrical Engineering, ITS campus Surabaya, Indonesia.Heat rate is studied and analyzed under different walls at a room, with 5 in 1 environmental meter to investigate the temperature both inside and outside in the room. Therefore, comparison effect of insulation system was shown in this paper. Calculation results, the total energy saving can be obtained in amount of 36 % and BEP can be reached in the 10 years. So, energy efficiency can be achieved.*

Keywords: *Energy saving,Polyurethane (PU) foam, Insulation*

I. Introduction

InstitutTeknologiSepuluhNopember (ITS) set the target reduction of greenhouse gases in a building and support act as a legal framework for promoting ECO Campus program. This program enables ITS to systematically identify, evaluate, manage and improve their environmental performance and practices.The efficiency energy can be made in various aspects, among others in the form of insulating system. Insulation system is required in a building for reducing heat losses to the environment. PU foamis one of the most efficient, high performance insulation materials, and enabling very effective energy savings with minimal occupation of space [1]. When it comes to insulating buildings, polyurethane foams are the cost-effective insulantfor new construction because it has low thermal conductivity, unmatched by any other conventional product. Low thermal conductivity can be used to reduce heat losses through the wall. The main functions of thermal insulation are conservation of energy, control of temperature, and control of heat transfer. Therefore, PU foamis good isolator. This achieved due to the formation of cellular void. The thermographic analysis revealed that the higher the PCM content within the PU foam, the lower the heat flows the specimen transmits when it is irradiated by means of a directional heat source [2]. Gas conduction in the closed cells accounts for approximately 60-80% of the total heat transfer. Evacuating the gas can greatly improve the thermal performance of the PU foam [3]. Therefore, the effective thermal conductivity decreases when the cell size becomes smaller [4]. Moreover, nanoparticle loading causes significant changes in the cellular structures of the foam. Cell dimension almost doubles with the inclusion of 3% by weight of TiO2 nanoparticles. Enhancement in strength and stiffness under flexural loading was phenomenal, especially with 3% TiO2 loading. On an average the increment in strength and stiffness was 30 % and 62%, respectively, over the neat system [4]. This study showsthe calculation result for energy savings in the rooms. This is aimed to comparison effect of insulating system in the room towards efficiency energy. This case study used the building of department electrical engineering in ITS.

II. Research Methods

A This wall is used in 4-storied buildingwith 8 rooms for each level. Measurement that is used in this study is a composite wall with 6 layers presentedin the Table 1. The dimensions of the building are 39.16x10.35x3.8m. These rooms consist of walls, windows (using glass plate), gypsum boards, and softwoods. In the study, heat rate through the wall can be calculated with thermal resistance analysis. Assuming fluid flow around of wall surface is a quiet both inside and outside room. So that heat transfer occurs by free convection. Assuming to calculation heat rate, heat transfer process is occurs in one dimensional and steady state condition. Theresult of temperature measurements obtained inside the room is27-29 0C and outsidethe room is 34 0C. Room air is at a uniform temperature and quiescent. The air is an ideal gas and constant properties. Temperature both inside and outside the room can be measured with 5 in 1 environment meters. The data of extents electrical engineering building can be measured by distance meter. While the composite of the wall is shown in Figure 1.

Table 9.Properties of Wall Materials [6]

Material	Thickness (m)	Thermal conductivity (W/m.K)
Brick	0.052	0.72
Cement plaster	0.04	0.72
Gypsum board	0.004	0.17
Softwood	0.003	0.12
Glass plate	0.006	0.76
Polyurethane foam	0.02	0.025

PU foam composite can be obtained in Federation of European Rigid Polyurethane Foam Association Report [1]. This data is used to analyze heat losses through the walls and calculatethe efficiency energy in a building. The layer is made up of rigid PU foam, with the thickness 20 mm, thermal conductivity 0.025 W/m.K, density 30 kg/m3, specific heat capacity 1.5 kJ/kg.K, heat storage capacity 4.73 kJ/m2.K, and excellent thermal insulation properties.
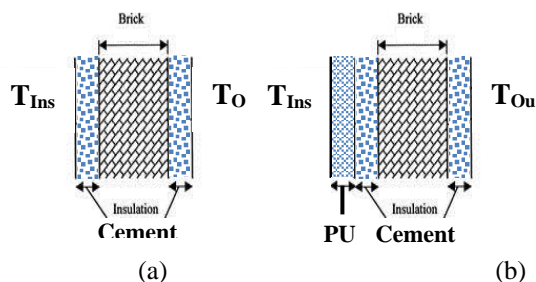
Figure 3. The physical structure of composite wall (a) Before insulation with PU foam and (b) After insulation with PU foam

Coefficient Convection Heat Transfer

All the air properties (ν, α, and κ)were evaluated at the mean film temperature as reported in:

$$T_f = \frac{T_{si}+T_{\infty i}}{2} \quad (1)$$

Where, T_f is the mean film air temperature. The average of coefficient convective heat transfer ($\bar{h}$) can be determined as:

$$\bar{h} = \frac{\overline{Nu_L}.k_f}{L} \quad (2)$$

The average values of Nusselt number ($\overline{Nu_L}$) can be calculated based on the free convection case along the wall height as:

$$\overline{Nu_L} = \left\{0.825 + \frac{0.387.Ra_L^{0.166}}{[1+(0.492/Pr)^{0.5625}]^{0.296}}\right\}^2,$$

$$Ra_L = \overline{Gr}.\overline{Pr} = \frac{g.\beta.(T_s-T_{\infty i}).L^3}{\alpha.\nu} \quad (3)$$

Thus,the thermal resistance for conduction and convection in a plane wall is:

$$R_{t,cond} = \frac{L}{k.A}, R_{t,conv} = \frac{1}{h.A} \quad (5)$$

So, heat loss through wall can be calculated as following:

$$q = U.A.\Delta T \quad (6)$$

Where, U is an overall heat transfer coefficient. The overall heat transfer can be calculated as:

$$U.A = \frac{1}{\frac{1}{h_i}+\frac{L}{k_1}+\frac{L}{k_2}+\frac{L}{k_3}+\frac{L}{k_4}+\frac{1}{h_o}} \quad (7)$$

And then, U factor can be calculated when the properties of materials composer in the wall are known. The heat losses through the wall can be obtained when the all of component have been discovered.

Results and Discussion

This study calculated heat losses in 4-storied building with dimension of eachbuilding is 39.16x10.35x3.8 m. In the calculation, each storeyhas 7 rooms,where 3 rooms are 10.74x10.35 m and 4 rooms are 3.47x3.47 m. These rooms consist of wall (the compositions are

brick and cement plaster), windows (glass plate), and doors (softwood). The results of heat losses calculation are presented on Table 2 together with applied floor storey, heat losses, and amount of loss per year (Rp). In the last column is given the percentage of the saving energy with PU insulation.

Floor Levels	Heat Losses (kW)	Heat Losses with PU (kW)	Amount of Losses per year (Rp)	Amount of Losses per year with PU (Rp)	Percentage of Saving Energy (%)
First	3.04	1.52	15,359,821	7,659,134	50
Second	1.77	1.31	8,912,564	6,628,260	26
Third	1.59	1.16	8,012,060	5,862,857	27
Fourth	1.66	1.20	8,373,810	6,061,278	28
Total	8.06	5.19	40,658,256	26,211,528	36

The results shown on the first floor that the heat losses in amount of 3.04 kW under normal condition. Using PU foam, the heat losses decrease to 1.52 kW. The percentage of saving energy on the first floor is achieved to 50%. On the second floor, heat losses in amount of 1.77 kW. Using PU foam, the heat losses decrease to 1.31 kW. The percentage of saving energy on the second floor is achieved to 26%. And then, on the third and fourth floor are decreased significantly of heat losses due to the effect of PU foam.

(a)

(b)
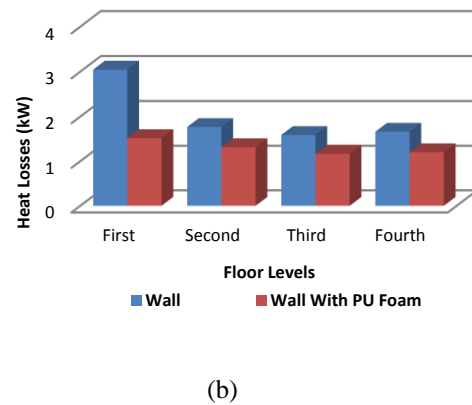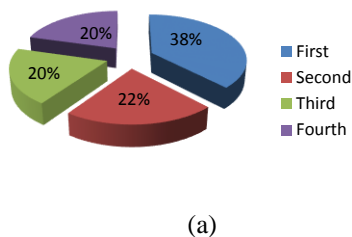
Fig 4.(a) The Percentage of heat losses through wall in the 4-storied building and (b) Comparison of heat losses between wall and PU foam

Figure 3.(a)this data shows the highest heat losses in first storied as big as 38%. This is due to the intensity using Air Conditioner in the rooms. Moreover, effect of equipment a heat release in the room need to be considered such as computer et all. Therefore, the using of PU foam can reduce significantly heat losses to environmental. This shows in the Figure 3 (b).This new insulation system by using PU foam decreased due to low thermal resistance material. The thermal resistance of PU foam is lower than of cement plaster, gypsum board, and brick. The low thermal resistance is achieved from material PU foam as an effective isolator. The heat isolator can be obtained by cell gas, density, temperature, and moisture [1].The reducing of heat losses can be increased of saving energy. This increasing is more pronounced in the case of PU foam for which saving energy is 36 %. So that cost of new insulation can be calculated. The cost of PU foam is 75,000 IDR/m^2 and the total wall area is 2042.55 m^2 on that 4 floor levels. The calculation results show the investment count is 153,191,400 IDR. And then, the total energy saving is 2.85 kW in amount of 14,446,727.57 IDR.New insulation system using PU foam can achieve Break Event Point (BEP) for 10 years.

Summary

Energy saving could be achieved by managing heat losses in a building. Heat losses can be reduced using PU foam on the wall surface. The reducing of heat loss can improvethe energy saving and decrease the cost of losses. The heat losses can occur by the conduction and natural convectionin the room. This process has been calculated by a thermal resistance analysis. When the PU foam was used, the heat losses to the environmentbecome lower than common wall.It has been shown that the heat losses for wall in the room highlydependon the thermal conductivity. In the present study, the total percentage of energy saving is 36 % and BEP can be achieved for 10 years.

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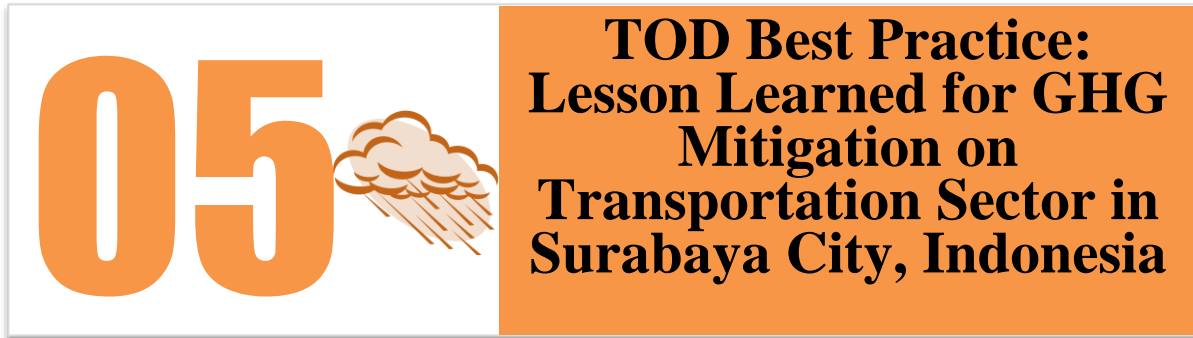
TOD Best Practice: Lesson Learned for GHG Mitigation on Transportation Sector in Surabaya City, Indonesia

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Abstract – *Surabaya is the second largest city in East Java, which shows the growth rate of vehicles is quite high. The transportation sector accounted for 5.48 million tons of carbon emissions per year, or about 96% of the total air emissions in the Surabaya City. Greenhouse Gas (GHG) mitigation in the transport sector is required to reduce the effects of climate change. Potential mitigation on transport sector is avoiding orreducing the distance travelled through integrated land use and transportation planning. TOD is the concept which integrates land use and transportation by creating area around the station or terminal more accessible with the use of transit modes or pedestrian/ bicycle. By TOD, development strategies of the area will encourage transit ridership and allow people to practice their activities without experiencing long transport distances. The experiences of TOD in Singapore, Portland, and Arlington shows there is significant effect of land use development around station to the use of transit modes and to reduce the distance travelled. Therefore, some of the lessons can be drawn to develop strategy of mitigation on transport sector in Surabaya by creating more attractive area around stations planned for monorail and tramway. Distance travelled can be reduced by mixed-uses development, high densities of housing and employment, pedestrian/bicycle-friendly network, park and ride design. Policy, institutional, and partnership supports are also needed to make TOD work in Surabaya.*

Keyword: *transit-oriented, mitigation, transport sector*

I. Introduction

Transportation activities have impacts on the increase of carbon emissions and also a major contributor to air pollution in urban areas. Based on the review of the Ministry of Environment (2005) showed that the use of motorized vehicles is a major source of air pollutants in major cities in Java such as Jakarta, Bandung, Semarang, and Surabaya (Indonesia Climate Change Sectoral Roadmap, 2010). Surabaya City also showed an increase in air pollution as well as the phenomenon of carbon emissions from the transportation sector. It can be seen from the increasing number of motorized vehicles with a growth rate of 5% per year (Surabaya in Figures, 2010). Increased the use of motorized vehicles directly resulted in increased the emissions of greenhouse gases (CO2). According to the Forest Monitoring

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Report of Surabaya, the transportation sector accounted for 5.48 million tons of carbon emissions per year, or about 96% of the total air emissions in the city of Surabaya (Rismanda, 2001 in Mahriyar, 2010). Meanwhile, in Action Plan of East Java set emission reduction target by 5.22%, equivalent to 6.2 million tonnes of CO2eq in 2020. Therefore, it is necessary to develop strategy of mitigation on the transport sector in the city of Surabaya.

There are three primary mitigations to reduce greenhouse gas (GHG) emissions in the transport sector (Indonesia Climate Change Sectoral Roadmap, 2010). These are: Avoid (i.e. avoid or reduce travel or the need to travel); Shift (i.e. shift to more environmentally friendly modes); and Improve (i.e. improve the energy efficiency of transport modes and vehicle technology). Avoiding or reducing the need to travel through careful land-use planning allows people to maintain their personal mobility while reducing the vehicle-kilometers travelled. It means that people still have possibility to achieve different human activities such as business, work, leisure and other social and cultural activities. Integrated, densely populated area,

working and shopping facilities and places for leisure allow people to practice their activities without experiencing long transport distances. A transit-orientated pattern of development further increases the land uses diversity and density along a highly efficient public transport. Integration of land use and transportation planning should be needed. As a result of sustainable transport measures already implemented, an individual may take a decision to travel with public transport modes or to reduce the vehicle-kilometers travelled. The number of travels and the total daily trip length can be reduced in this way due to mixed land use, and shorter distances to trip destinations.

The concept of TOD (Transit Oriented Development) is an evolution of urban planning concept that emphasizes on the principles of integration between land use and transportation. This concept is an elaboration of Smart Growth City concept that guides the development of areas around transit points (terminal, stations, busesstop) to improve the accessibility of areas and to provide the ease of mobility. TOD practices in worldwide showed success in overcoming the congestion of the city, seen from increasingly mode shift to transit usage. The study which was conducted in 214 stations in Seoulshowed that the rate of transit ridership is influenced by the characteristics of the land use in the area around stations (Sung and Oh, 2011). So, reduction of automobile dependency can be done by integrating transit system with land use development based on TOD principles.

Mass rapid transit system had been planned to reduce the automobile dependency and vehicle-kilometers travelled in Surabaya. It will connect the east-west side of city by monorail and south-north side by tramway. It needs to consider the characteristics of area around the planned station to avoid or reduce the need to travel with automobile. So, this paper aims to identify the land use strategy of transit area in order to encourage the future transit ridership and to reduce distance travelled in Surabaya. Approach used in this study is based on best practice of TOD implementation in worldwide.

II. Mitigation using TOD Concept

Climatechange mitigation is efforts to reduce the risks of climate change impacts through activities that can reduce GHG emissions and/or increase GHG absorption from various emission sources. Emission sources are activities on transport sector, industry, waste, etc. GHG emission on transport sector is calculated from the level of energy consumption for transportation activities. So, the strategy of mitigation on transport sector is efforts to reduce the consumption of energy by reducing distances travelled, shifting to the most environmentally friendly transport modes, or improving the energy efficiency of transport modes and vehicle technology.

Integration of land use and transportation planning aims to reduce the distance travelled. TOD is the concept that integrates transport network with development oriented to the transit point. Theoretically, there is no universal definition of the concept of TOD because its meaning may vary by location or different place (Cervero et al, 2004). Some definitions are associated with smart growth and sustainability principles. Other definitions are related to the design characteristics of environment that emphasizes the pedestrian supportive environment, mixed land use, high density around station. Then, the local government of United States defines TOD specifically through FAR (Floor Area Ratio) and minimum distance to the rail station which is often associated with zoning regulations (Cervero et al, 2004). In principle, TOD aims to create an environment that reduces the use ofautomobile and encourage the use of public transport (buses, trains, and so on) through the promotion of good accessibility and mobility. Therefore, the definition of TOD relates to land use (housing, commercial, open space and so on) in station area with mixed-land uses, non-motorized supportive network, and high density in station area. This definition as quoted on http://en.wikipedia.org that:

“A transit-oriented development (TOD) is a mixed-use residential or commercial area designed to maximize access to public transport, and often incorporates features to encourage transit ridership. A TOD neighborhood typically has a center with a transit station or stop (train station, metro station, tram stop, or bus stop), surrounded by relatively high-density development with progressively lower-density development spreading outward from the center”

The definition of TOD concept emphasizes on the integration of land use around stations with transit network systems that serve it. TOD sets land use and density pattern around the station. High density with mixed-land uses should be close to the transit station.

The land use system is supported by roads network connecting to the station location. The roadsnetwork should have a circulation that supports the use of non-motorized modes (Watson et al, 2003). How the concept of TOD in integrating land use with transportation systems is clearly visible from densely populated area, mixed-land use, friendly design to pedestrians/bicyclists, network-connected circulation, as well as the park and ride facilities supports.TOD is a promising concept of vitality and development around station by creating a friendly environment for pedestrians, mixed land use, and good connectivity with transit location. As the result, number of travels and the total daily trip length can be reduced in this way.

III. Methodology

The method used in this study relates to data collection and analysis methods. Method of data collection was conducted by secondary survey on the agency of government. The data used in this study was gained from Transportation Department of Surabaya (Dinas Perhubungan) and Surabaya City Development Planning Agency (Badan Perencanaan Pembangunan Kota Surabaya).

The method of analysis used in this study is a descriptive analysis technique to overview the plan of mass rapid transit development in Surabaya and discuss how the success experience of mass rapid transit development in worldwide by applying transport and land use development strategy to influence the use of transit modes and reduce the distance travelled. Literature study is conducted to describe best practice of TOD implementation in developing stations area. Planned stations in Surabaya are Sentra Bulak, PTC, Pasar Keputran, Joyoboyo for monorail stations and Joyoboyo, JMP, Pasar Tunjungan, Gapura Surya for tramway stations.

IV. Analysis And Discussion

IV.I The Plan of Urban Mass Rapid Transit in Surabaya

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Trip characteristicinSurabaya was dominated by the use of motorcycle(50.95%) andprivate cars(1.60%), only 5.96% the trip with public transport (Transportation Department of Surabaya, 2012). It means that the tripin Surabayais dominatedbythe use ofprivatemodes. The result of research by Mahriyar (2010) shows that the distance travelled with private modes averaged on 7-11 kilometers. It shows longer distances to trip destinations.

The plan of urban mass rapid transit in Surabaya aimstoprovidean alternative mode inconnecting north-southside byTramway, and theeast-westside byMonorail. An overview ofthe technicalspecifications ofmass rapid transit planinSurabaya is shown in Table 1 below.

Table 10.Overview of Technical Specifications Plan of Mass Rapid Transport in Surabaya

No.	Plan	Monorail	Tramway
1.	Length of corridor	26,21 Km	18,18 Km
2.	Alternative route	Terminal Joyoboyo - Raya Darmo (Taman Bungkul) - Raya Darmo (Santa Maria) -Urip Sumoharjo - Basuki Rachmad-Embong Malang - Pasar Blauran - Bubutan (Halo Surabaya) - Tugu Pahlawan - Indrapura DPRD Jatim - Indrapura Parangkusuma - Indrapura (Pertigaan Rajawali) - Perak (Ikan Kerapu) - Perak (Tanjung Sadari) - Perak (Teluk Betung) - Rajawali (Kalisosok) - Rajawali (Taman Jayengrono) - Veteran (BCA) - Tugu Pahlawan (Gubernuran) - Kramat Gantung – Tunjungan - Gubernur Suryo (Grahadi) - Panglima Sudirman (Bambu Runcing)	Sentra Bulak – THP Kenjeran – Ken Park – Mulyosari Utara (Jembatan) – Mulyosari Tengah (Central Park) – Kejawan Putih Tambak – Bundaran ITS – Kertajaya Indah (GOR) – Manyar Kertoajo (Samsat) – RSUD Dr. Soetomo (lap. Hoki) – Stasiun Gubeng – Taman Mukti Mulia – Keputran – Jembatan BAT Ngagel – Terminal Joyoboyo – Mjd. Sungkono (Ciworld) – Mjd.Sungkono (Bundaran tol) – HR Mohammad (Giants) – HR Mohammad (Patung Kuda) – Bukit Darmo Golf Boulevard – Pakuwon Trade Center

3.	Number of stations	4 (Sentra Bulak, PTC, Pasar Keputran, Joyoboyo)	4 (Joyoboyo, JMP, Pasar Tunjungan, Gapura Surya)
4.	Number of rail stops	17	18
5.	Distance between rail stops	Minimum of 500 meters	Minimum of 500 meters
6.	Occupant capacity	184-254 occupants	220-225 occupants
7.	Avarage of headway maximum	15 minutes	4 minutes

Source: Pra-Feasibility Study of Mass Rapid Transportation, Transportation Department of Surabaya, 2012

Potency of shifting to use monorail and tramway was estimated around 93%-96% from cars usage and 65%-84% from motorcycle usage (Surabaya City Development Planning Agency, 2013). It was estimated can reduce the number of travel with cars around 164-1739 vehicles per hour and 1499-2718 vehicles per hour with motorcycles. So, it requires strategy to realize the potency of such modes shift and number of travel reduction. Some experiences in worldwide show its success in reducing the number of travel and influencing mode shift by land use development strategies around the stations. Some ofthe plannedstations in Surabaya for monorail and tramway (Sentra Bulak, PTC, Pasar Keputran, Joyoboyo, JMP, Pasar Tunjungan, Gapura Surya) were dominated by the land use of commercial and residential area. Currently, there are nospecificdevelopmentplansaround the stationsarea. Therefore, the experiences of TOD in worldwide can be lessons learned to develop area around stations in reducing the distance travelled as strategy of mitigation on transport sector

IV.II TOD Best Practice in Worldwide

TOD is a viable model for transportation and land use integration in many developed and rapidly developing cities of the world (Cervero in Curtis et al., 2009). Historically, several cities in Asia have been oriented to transit, but increasingly income and vehicle ownership as well as increasingly car-dependent built form caused the use of transit mode less popular. Singapore, Portland and Arlington had best experiences in implementing TOD principles.

Singapore is a good model of TOD (Cervero in Curtis et al., 2009). Integration of land use and mass rapid transit system has been the concept of urban growth pattern in Singapore. The pattern of Singapore's urban development has been influenced by the changing mode of urban transport and different ways of moving people in the city, from the traditional transit service such as streetcars and trolley buses, to the modern automobile and road system, and to MRT system (Yang and Lew in Curtis et al., 2009). It has been highly influenced by the plan of new towns development. Therefore, many policies on urban land use were developed in order to change the mode of urban transport usage. Government's initiative had significant influence in making TOD happened in Singapore. How the TOD principle was applied in urban planning can be seen from the 1970 Concept Plan, which was driven by decentralization strategy of urban growth along the transit corridor for relieving the congestion in the city center. New town planning design of Singapore had been transformed to become more transit supportive from 1950s to the 1990s. The new town Queenstown prioritized cars-friendly design over pedestrians in early forms during the 1950s to 1960s. However, there was land use change around the Queenstown station area when the start of the operation of East-West line in 1987. The retail node was moved from the fringe to the center of the walkable transit station area from 1958, 1980 to 2003 (Curtis et al., 2009). MRT system had influence the change of land use around the station area. The urban design of new towns in the 1990s was more pedestrian-friendly networks of road and park that incorporates mixed-land uses system, in which the MRT station as the center of neighborhood. TOD had also been applied in the new town of Sengkang. The new town of Sengkang was guided by transit-oriented urban design principles. The planning of land parcels, circulation, road structure, parking design, building layout and typology was driven by their relationship to the transit station with pedestrian-friendly design support and better integration of the mixed-use development. There was significant correlation between land uses development around station area with ridership in Singapore. The evidence showed that MRT ridership appears steadily increasing as the distance of the new towns from the center increases and in densely populated (Yang and Lew in Curtis et al., 2009). By TOD principle, the change of travel behavior from automobile to transit mode usage was driven by integration of land uses and mass rapid transit system in Singapore. This travel behavior change can reduce the distance travelled to be shorter to trips destination.

Portland's experiences with TOD have evolved over 25+ years (Arrington in Curtis et al., 2009). TOD is one of the primary policies in Portland. TOD was applied to help maintain compact urban form in reducing dependence on the automobile and supporting reinvestment in centers and transit corridor. TOD in Portland was planned and implemented at multiple levels by the agencies of TriMet, Metro and PDC (Portland Development Commission). By the experiences of TriMet, the evidence showed that linking transit and land use results in more transit ridership. During 1990-2006 TriMet's ridership has

grown faster than the use of automobile (Arrington in Curtis et al., 2009). The way of TriMet to make TOD work was done by following strategy:

- planning the design and density of area around the stations
- determining land costs to get the affordability in TODs
- turning parking and ride into TODs
- modifying stations location to facilitate supportive development
- funding local government planning to get supportive policies in place
- investing the savings from rail construction to create TODs

Metro's experience shows that it requires funding support and partnership in making TOD work. Another good experience was showed by PDC in planning The Pearl District. The Pearl District is now an established mixed use neighborhood of high density housing, parks, art galleries, boutiques, cafes, and restaurants (Cervero et al, 2004 in Arrington in Curtis et al., 2009). The Portland streetcar was the catalyst in urban form transformation in this district. It supported with the Development Agreement which determined the city's main goals such as to preserve history building, increase density to attract business, and promote the use of transit. By the agreement, the district offered an affordable housing, public open space and parks, local streets, sidewalks, and utilities. The district was been more attractive for business and living. Therefore, the use of streetcar is popular among residents and visitors.

Arlington's experience of TOD was conducted with the effort to both redevelop a declining commercial corridorand ensure future riders for the transit system. Metrorail subway was a catalyst for the development of county's low density commercial center. The "bull's-eye" concept proposed focusing on the intense development in station area, with building height of 18-20 floors for residential and 10-12 floors for office building. Redevelopment occurred within a quarter-mile walking radius of stations, and included a mix of uses with a major residential uses. The planning principles that guide the redevelopment include the following (Leach in Dittmar and Ohland, 2004):

- highest density uses would be concentrated within walking distance of Metro station
- mixed-uses development would be required, with integration of high-quality pedestrian environments, in order to produce an active, vibrant core area during the day and evening
- each station are would serve a unique function and have a well-defined identity: Rosslyn as a major business and employment center; Court House as a government center; Clarendon as an urban village; Virginia square as cultural, recreational, and educational center; and Ballston as a new downtown in central Arlington
- minor adjustment would be made to the street system

By many measures, the redevelopment of the Rosslyn-Ballston corridor has been highly successful. It can be seen from the increasing land and improvement value in county. The other measure of the success of TOD implementation is the increasing transit riders use Metro during the morning peak period. Summary of strategy to integrate transport and land use with TOD in three cases can be seen as Table 2 below.

Table 11. Strategy of Transport and Land Use Integration with TOD

No	Case	Integration Strategy	
		Land uses strategy	Transport strategy
1.	**Singapore**	• **Mixed-land uses development around the station area** • **High densely populated in area near with the station** • **Compact urban form**	• **The use of LRT and MRT system** • **Well-connected circulation between road, parks pedestrian way and station** • **The station of LRT and MRT is located at the new town center**
2.	**Portland**	• **Transit friendly land use plan around light rail stations** • **Forming park and ride design** • **Offer an affordable housing and other amenities in stations area** • **Propose high density urban form**	• **Pattern of street grid around the stations. The stations is located as focal point** • **Transportation improvement was essential to develop the area by providing local streets, sidewalks, and utilities.**

3.	**Arlington County**	• **The uses of land within walking distance of station would be highest density** • **Offering a rich mix of uses by promoting mixed-land uses developmen t around station** • **Defining the unique function for each station and linking each other**	• **Regulation of minimum of occupant vehicle on morning and evening** • **Providing highway and a grid of local street to manage traffic** • **Improvement of sidewalk network with wider sidewalk, curb ramps, pedestrian lighting, street trees, and other amenities** • **Providing bike lanes throughout the corridor and secure indoor bicycle parking**

V. Conclusion And Lessons

The experiences of applying TOD in worldwide give some hopes to solve congestion problem by creating the attractive area around the station to influence travel behavior change on transit mode usage. It can be a strategy of mitigation of GHG emissions from transport sector by reducing consumption energy for transportation activities. Travel behavior change to mode transit and non-motorized usage can reduce the number of travel and make shorter distance to trip destinations. Surabaya City had planned the mass rapid transit system to solve the high dependence on automobile and reduce the number of travel with cars and motorcycles. Therefore, it is necessary to consider applying TOD principles in Surabaya City for influencing mode shift to monorail and tramway as a strategy of mitigation on transportation sector. Based on the experience of TOD in Singapore, Portland, and Arlington, some lessons learned to integrate transport and land use development can be drawn as following notes:

- Station area development should be mixed-land uses, high residential and employment densities and integrated with pedestrian/bicycle-friendly networks. Supporting of park and ride design can be considered to give alternative mode of automobile and transit.
- Zoning of station area is necessary to maintain the uses of land around the station, to plan the mixed-land uses and pedestrian-friendly design. It ensures the station area have an affordable price of land, offer the living amenities, and be attractive place. The more attractive station area created, the use of transit mode will be more popular.
- Planning for TOD is necessary to do for land uses management strategy and dependence of automobile reduction. Plans and development standards is not enough. Transformation of urban forms takes time and funds, requires legitimacy, and partnership. Policy, institutional and legal aspect support is needed to make TOD happened in Surabaya.

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Amplitude Variation with Offset: Case History in Water Table and Lithological Reflection

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Abstract – *The aim of this paper is to prove that the reflection seismic method available to image the water table reflection. It is to response Clement et al (1997) statement that "Seismic refraction is the only technique to image the water table". Two sets of seismic records from a difference subsequent field survey have been processed using the similar processing sequences. Both of them image a clear reflector. Edwinstow seismic record presented the water table reflector while the other is Croft set of record that presented the lithological reflector. The application of AVO analysis to CMP gathers from Edwinstow field records shows the characteristic of increase sharply amplitude with increasing angle of incidence for second critical reflection. On the other hand, the characteristic of decreasing amplitude with increasing angle of incidence for second critical reflection was presented by Croft field records. In this way the water table reflector is clearly distinguished oppositely from lithological boundaries. The results of both field survey and its interpretation are validated by equipment asessments that includes: seismograph, Promax processing system, and geophones test.*

Keywords: *geophysics, water table, shallow, seismic, reflection, AVO.*

I. Introduction

Amplitude Variation with Offset (AVO) analysis uses the phenomenon that reflection coefficients vary with source-receiver offset, which is observed on CMP pre-stack gathers (Vavrycuk & Psencik, 1998; Ruger, 1998; Lindsay & Ratcliff, 1996). This analysis has been used successfully by Ostrander (1984) to demonstrate that gas sand reflection coefficients vary with increasing offset. He also showed how to utilize the variation behavior as a direct hydrocarbon indicator on real data. AVO analysis is also used successfully as a hydrocarbon exploration tool (Santoso et. al. 1996; Sheriff & Geldart, 1995; Castagna & Backus, 1993,).

Castagna & Backus (1993) described AVO, as "a seismic lithology" tool, which provides an improved model of the reflection seismogram. These properties might be directly related to lithology and fluid content. AVO analysis has also been used to identify the reservoir fluid, such as gas, water and oil by plotting the value of the P-wave velocity against Poisson's ratio (Santoso et. al. 1996, Mustain, 2009). Skidmore and Lindsay (1997) concluded that AVO analysis helps seismic imaging in deepwater environments.

The aim of the author here is to present an opportunity to use result of AVO analysis for identification of water saturated sandstone (water table in near surface) to be compared to the solid reflection. The water table should theoretically produce a clear AVO response, which very different from a lithological boundary. Therefore, we can use this manner to identify the water table by shallow seismic method as hydrological reflection. The method is to use the result of AVO analysis from the data over the land in order to image water table reflection, and to collect data for solid reflection. Next, we will show the observed AVO anomalies for both reflections, then there where should been confirmed by recorded calibration system and processing calibration system. Finally, there were

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would been established with the AVO analysis curves.

II. Reflection Coefficient

Referring to the simple form of Zoeppritz's (1919) equation about energy absorbsion that can be expressed in term of the change of amplitude for normal incidence (assuming up to 150); we need to expand further the general case where the angle of incidence exceeds 150. Consequently, the equations for the coefficient of reflection and transmission (as a solution of the wave equations) become more complicated. This includes the term of (the angle of incidence). Tooley et al (1965) showed the variation of amplitude with angle of incidence for several sets of parameters.

Figure 1 shows the P-wave reflection coefficient for various P-wave velocity ratios (v2/v1). The critical angle varies as the variation of P-wave velocity ratio, and gives this figure its complex appearance. When there were no impedance contrast or the velocity ratio is unity, then the reflected energy is zero (no curve for this case). The two peaks for v2/v1>1 occur at the critical angle for P- and S-waves, respectively (Sheriff and Geldart, 1995). In the special situation where one medium is a fluid and the other is a solid, the large amounts of S-wave energy are generated in the solid medium at large angles of incidence by P-wave incident from either medium (Tooley et al, 1965).
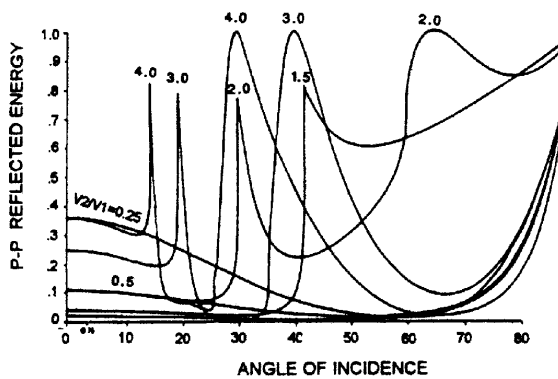
Figure 4. The effect on the P-wave reflected compression energy of varying the compression velocity ratio (V2/V1 or 2/1) (source Sheriff and Geldart, 1995)

$$R_P \approx \frac{1}{2}\left[1-4\left(\frac{\beta^2}{\alpha^2}\sin^2\theta\right)\frac{\Delta\rho}{\rho}+\frac{1}{2}\sec^2\theta\left(\frac{\Delta\alpha}{\alpha}\right)-4\left(\frac{\beta^2}{\alpha^2}\right)\sin^2\theta\left(\frac{\Delta\beta}{\beta}\right)\right]$$

(1)

$$T_P \approx 1-\frac{1}{2}\left(\frac{\Delta\rho}{\rho}\right)+\left(\frac{1}{2}\sec^2\theta-1\right)\left(\frac{\Delta\alpha}{\alpha}\right)$$

(2)

Shuey (1985) made a simplification of these equations by changing β and Δβ with σ and Δσ with;

$$\frac{\Delta\beta}{\beta}=\frac{\Delta\alpha}{\alpha}+0.5\Delta\sigma\left(\frac{1}{1-\sigma}-\frac{2}{1-2\sigma}\right),$$

$$\beta^2=\alpha^2\frac{1-2\sigma}{2(1-\sigma)}$$

$\Delta\alpha = \alpha_2 - \alpha_1$ and $\alpha = (\alpha_2+\alpha_1)/2$, $\Delta\beta = \beta_2-\beta_1$ and $\beta = (\beta_2+\beta_1)/2$

$\Delta\rho = \rho_2-\rho_1$ and $\rho = (\rho_2+\rho_1)/2$, $\Delta\sigma = \sigma_2-\sigma_1$ and $\sigma = (\sigma_2+\sigma_1)/2$

$\theta = (\theta_2+\theta_1)/2$ with $\frac{Sin\theta_1}{\alpha_1}=\frac{Sin\theta_2}{\alpha_2}$

Then with further modification derived by him, the relation becomes:

$$R_P \approx R_0(1+P\sin^2\theta+Q(\tan^2-\sin^2\theta))$$

(3)

Where:

$$R_0=\frac{1}{2}\left(\frac{\Delta\alpha}{\alpha}+\frac{\Delta\rho}{\rho}\right),$$

$$P=\left[Q-\frac{2(1+Q)(1-2\sigma)}{1-\sigma}\right]+\frac{\Delta\sigma}{R_o(1-\sigma)^2}$$

$$Q=\frac{\Delta\alpha/\alpha}{\frac{\Delta\alpha}{\alpha}+\frac{\Delta\rho}{\rho}}=\frac{1}{1+\frac{\Delta\rho/\rho}{\Delta\alpha/\alpha}}$$

R_0 is the reflection coefficient for normal incident

The simplification uses an assumption that Poisson's ratio is the elastic property most directly related to the angular dependence of reflection coefficient (Shuey, 1985). This also

made a further modification to separate out the factor R_0 as the amplitude at normal incidence. It is easy to see that R_0 is an appropriate reference for $\theta \approx 0$. For intermediate angles ($0<\theta<30$ degree) or second critical angle, the reflection amplitude is connected to the parameter P which is the sum of the two terms. The real component of that parameter is in the ratio $\Delta\sigma/R_o$.

In the next following years, Hilterman (unpublished and private communication reported by Sheriff and Geldart, 1995) wrote the form of:

$$R_p \approx R_0\left[1-4\left(\frac{\beta^2}{\alpha^2}\right)\sin^2\theta\right]+\frac{\Delta\sigma}{(1-\sigma)^2}\sin^2\theta+R_0\left(\frac{\Delta\alpha}{2\alpha}\right)\left[\tan^2\theta-4\left(\frac{\beta^2}{\alpha^2}\right)\sin^2\theta\right]$$

(3.a)

He made a further approximation for intermediate angles that neglects the third term (dominated by velocity dependence). For a half space medium this is given by Al-Ghamdi et al (1998):

$$R_P \approx R_0 \cos^2\theta + 2.25\Delta\rho\sin^2\theta$$

(4)

The next extension for these conceptions is the autor will make critical analysis for intermediate angle. This is specially to distunguis the water table reflection from the lithological reflection as normally stratigapical reflection in near surface. The simplifacion of Hilterman (in Sheriff and Geldart, 1995) to neglect the third term due to the dominated of velocity dependency is to be back. The reason is the velcity dependency can not be neglected due to significancy value of difference velocity of saturated water sandstone and unsaturated sandstone. Therefore the formulation after Al-Ghamdi et al (1998) is given:

$$R_p = R_0\left[cos^2\theta + \frac{\Delta\alpha}{2\alpha}(\tan^2\theta - \sin^2\theta)\right] + 2.25\,\Delta\rho\,\sin^2\theta$$

(5)

III. Numerical Implementation Model

Clearly the mathematical AVO model is different from the physical model. The physical model (figure 1) shows the ideal natural condition. The model can treat the signal continuously from normal incidence to wide angle (90o) in the laboratory's experimentation, and the 1st and 2nd critical angle should appear. However, the mathematical model cannot cover the complete formulation as a complex form (Koefoed, 1962). Only the real part can be used in practice and this has to be approximated for three zones: normal incidence, intermediate angle, and wide angle (Shuey 1985, Ostrander, 1984). In this case history (study) we only used intermediate angles 24o was the first critical angle and 35o was the widest data provided. Consequently, we cannot see any critical angle reflection after 35o.

The AVO curve for three different approximation formulae (Aki & Richards 1980; Shuey 1985; and Hilterman by Sheriff & Geldart 1995) were have been calculated for a water table reflection in a pure sandstone with 30% porosity. Figure 2 shows the calculated curves of different formulae for intermediate angles. Each formula has different specifications. Aki & Richards (1980) reported that their formula is only valid when; $\Delta\alpha/\alpha$, $\Delta\beta/\beta$, and $\Delta\rho/\rho$ are small and $\theta < 10^0$ if $\alpha_1 < \alpha_2$. Although the amplitudes are not the same for normal incidence, the lithology and water table curves have opposite trends (decrease and increase respectively curve of A&R-lit and A&R-wt). This is because Aki & Richards formula does not separate the Ro factor while the other formulae do.
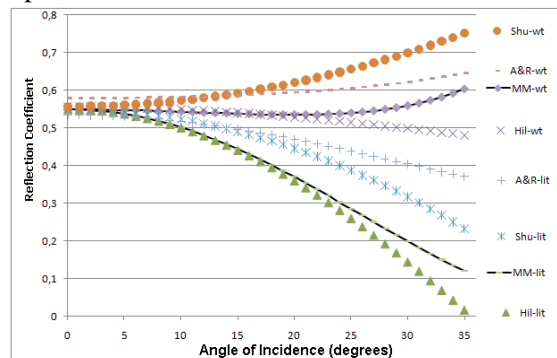
Figure 5. The curve of AVO for water table in typical sandstone of 30 % porosity using; 1. Hilterman formula (eq. 4) as Hil-lit and Hil-wt, 2. Shuey (eq. 3) as Shu-lit and Shu-wt, 3. Aki & Richards (eq.1&2) as A&R-lit and AR-wt, and 4. Mustain Modification form

The implementation of the Shuey formula in this case study gives the value of the dimensionless parameter of P = -0.1 for lithology and P = 0.9 for water table. The curve of Shu-wt shows that the relative amplitude increases sharply as the water table (figure 2). On the other hand, for the same effect the curve of Shu-lit decreases. This is important evidence that this formula can indicate water table anomalies. The middle term of the Shuey formula (eq. 3) controls $R_{p,}$ and the last term is always positive. This implementation of the Shuey formula produces a value R_o = 0.56, very close to the coefficient reflection value from R_c versus porosity curve of water saturated sandstone that gives R_o = 0.53 for 33% porosity. There is a reasonable agreement between the ideal calculation of the R_c versus porosity curve and the mathematical implementation of Shuey formulae.

The Hilterman (by Sheriff & Geldart 1995) approximation also can be used to this application. For the Lithology case, the Hil-lit curve has a same negative trend to the Shu-lit curve at most angles. However, for the Water Table gives rather a different result, Hil-wt curve shows negative trend (amplitude decreases with increasing of angle of incidence) while the Shu-wt is positive (amplitude increases with increasing of angle of incidence). This is because the Shuey approximation is more relevant for a case using intermediate angles. On the other hand, Hilterman uses the approach of half space of velocity (V_2 = $2V_1$). Both Shuey and Hilterman approximations clearly prove that the lithological boundary and water table (as hydrological boundary) have opposite trends, decreasing and increasing respectively. This also indicates that $R_p = R_o$ for $\theta \approx 0$.
One importance point in this paper is the proposed formula of equition 5 to be made on the implementation as the alternative formula in order to the water table reflection. These cases are also would be fixed as the mathematical forms for water table reflection (MM-wt) and lithological reflection (MM-lit). The most different result gives us very interested interpretation, the curve is MM-wt on the range of 25^o to 35^o. The curve sharply increases on that range i.e. the range of the second critical or intermadiate angle. This is very good evidence that the amplitude go up on this offset for water table reflection.

Observed AVO of Edwinstowe Section for Water Table Reflection

Part of Edwinstowe (25 km north of Nottingham, UK) common offset gathers has been chosen for AVO analysis (Mustain, 2002). Common offset gather for this case study is have been chosen, figur 3. A possible reason is the homogeneous nature of the subsurface geology. There were some processes required to reduce factors that affect the seismic amplitude, especially factors with offset dependence.

Referring to the physical model (figure 1) as a representation of a complex formulation for normal or natural condition, it is representative of the Edwinstowe condition that has a compression velocity ratio V_2/V_1 of 2.5. The intermediate angle range is from 24^o (as the first critical) to 50^o. The oobservational data is only available for the range of angles from 24^o to 35^o. Within this more limited range, the reflected energy decreases sharply with increasing angle of incidence. The model curves in figure 1 are computed for boundaries with a lithological contrast, where the partition of energy is mainly controlled by the properties of the matrix of the rock and not its fluid content.

Figure 6.a part of Edwinstowe record as the result of 15 Common Offset stack (source Mustain 2002)

Figure 4 illustrates the result of AVO record from figure 3 and mathematical model of both lithological and hydrological boundaries (reflections). The stack-wt (figure 4) is the result of stacking using common offset by Promax, while the Manu-wt is the result of manual averaging from 15 shot records. Both ploted stack and ploted manual have the expected trends i.e. increasing amplitude with increasing offset. These curves increase sharply from 28.1^o until

32°. This increase is good evidence that the reflector is a hydrological boundary (water table), oppositely if the curve decreased with increasing offset then it would be a lithological boundary (figure 4, solid and dashed line are the mathematical model for water table and lithological boundary respectively).

The error bars, from standard deviation of the averaging record (from manual picking) is 17.5 % with a maximum deviation of 29 %. Statistically, this distribution record is normal, as indicated by the maximum deviation among the data being greater than its standard deviation. The instrumentation test gives a result of the seismograph channel having an average deviation of 0.3%, and all geophone tests gives average deviations of 9.7%, with processing system tests indicating deviations of less than 2% (1.20 %, 0.02 %, and 0.81 % for error of: f-k filter, top mute, and band pass filter respectively). Thus it is reasonable to conclude that the variation of amplitude is statistically caused by variation in offset, not the instrumentation. To confirm this, it will be proved by AVO analysis of a known lithological boundary, which shows that the amplitude decreases with offset.
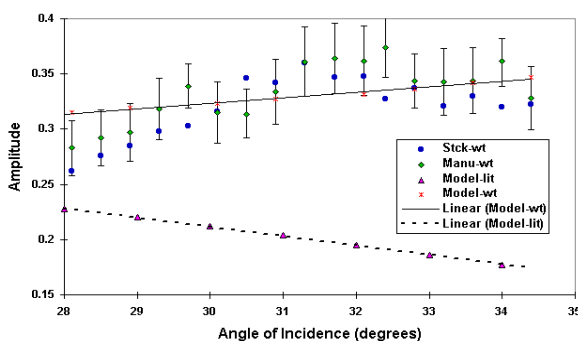
Figure 7.AVO analysis of Edwinstowe record as average (promax stacking as Stack-wt and manual averaging as Manu-wt) of 15 common offset gathers with average deviation of 17.5 % as error bars, comparing to the mathematical model using Shuey formula as lithological and water table boundary (Model-lit and Model-wt)

1. Observed AVO of Croft Record for Lithological Reflection

The main purpose of this section is to apply AVO analysis to a reflection from a lithological boundary. This boundary will prove that the amplitude decreases with increasing offset in the intermediate angle (between P and S critical angles). Previously, we have proven that the amplitude increased with increased offset for water table reflection as hydrological boundary.

This investigation needs data with appropriate post critical reflection, which we can analyze the trend of amplitude Vs offset for the same purpose as Edwinstowe survey. Croft records that had been taken one year before Edwinstowe are appropriate data for this purpose. This has a simple geophysical target, of a flat lying reflector. The records have a maximum offset of 136m, which is adequate when using AVO analysis for a depth of target of about 100 m. This gives us a chance to analyze ranges beyond the critical angle.

The field area is located near Croft Quarry (SP 523 956) South Leicester, UK. The site is a small field west of Coventry road, beside the quarry entrance. Figure 5 shows the plan of the shot line of seismic survey. It is a covering of 100-200m of bedded sediment (Mercian Mudstones underlying Sherwood Sandstone) unconformable overlying a granitic intrusion. Mudstones are flat lying, and no ray paths we considered to have entered the granite. This is geologically similar to the Edwinstowe location analysed for water table reflection. The primary interest of this site is to determine the depth of Mesozoic/Palaeozoic cover over diorite rock east of Croft Quarry.

The processing sequence is similar to the processing for both the synthetic and the Edwinstowe records. Figure 6 shows the final stack. The figure shows that there are three simple layers with first and second boundary at around 100 and 150m respectively, meaning the basement starts in the third layer. This also indicates that the zone below this boundary has no significant layering. This may be due to the very limited length of record.
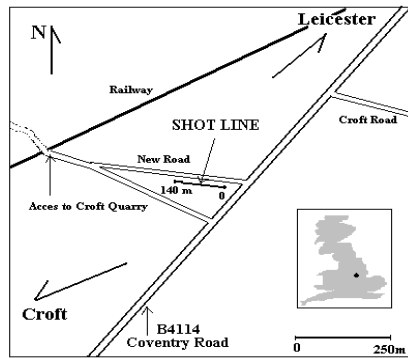
Figure 8.The plan location of shot line of seismic survey
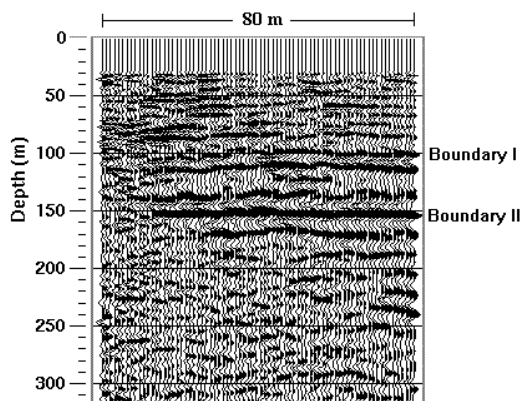
Figure 9.The final stack of Croft record

The prominent reflector at the first boundary at 100 m is interpreted as a contrast in velocity from 1900m/s to 4150m/s. The reflector is very difficult to interpret as the depth of Mesozoic/Palaeozoic (Mercian Mudstone) cover over diuretic rock East of Croft Quarry, is between 100-200m thick. The velocity of the second layer is too high for diuretic rock. Regarding to geologists within the department (Geology in Leicester University, UK) and the consensus of opinion, if there is a high velocity in the Croft data then it is probably (1) Stocking ford shale’s (Cambrian) or (2) Gypsum in the Mercian Mudstone (but not halite).

Acording to the amplitude record for AVO analysis, CMP gather is the best section for analysis (Ostander 1984, Sheriff and Geldart 1995). CMP gathers were also used in this observation. There are 22 CMP (numbers 50 to 72) gathers, which include the maximum offset that we have (136m).

The P-wave critical angle in this AVO analysis is calculated from the estimation of critical offset (can be seen in the pick of amplitude curve in figure 7). Thi is in distance between 108 to 110 m and 100m of reflector depth. From this calculation, the critical angle is about 28o. This is can be accepted by using the velocity contrast in the reflector, for 1900 to 4150 m/s that give the critical angle of 27o. The different of 1o is in the range of error bar of Vrms that less than 7 %.
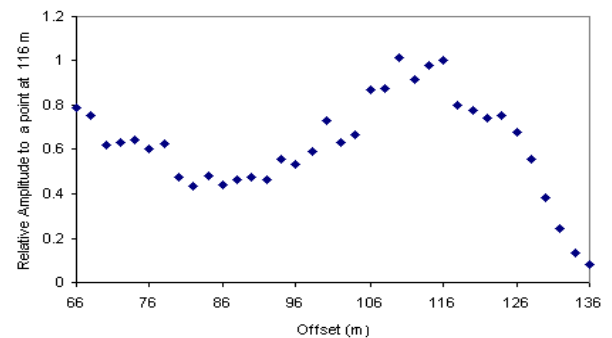
Figure 10.the AVO observation from the Croft record shows the P-wave critical angle at about 110 m

This evidence proves that the sub-critical angle has an amplitude variation with offset by providing the curve with different ways of shooting that have similar curves. Figure 8 shows the curve of AveSR2&3 that has an amplitude variation with offset from East-to-West shot. The opposite direction (West-to-East shot) is illustrated by the curve of SR48 and SR49. All the curves have similar trends, going down from 66m, having a minimum of 80-90m, and then rising to the critical angle 110-116m. All of these curves have average standard deviations of 0.57 after reducing 76 % from 3.3 (also in standard deviation) by normalization using the factor of the square root of the energy and by a random filter of 7 % wing smoothing data. This remaining error (standard deviation of 0.57) is reasonable due to the variation in geophones we have tested.
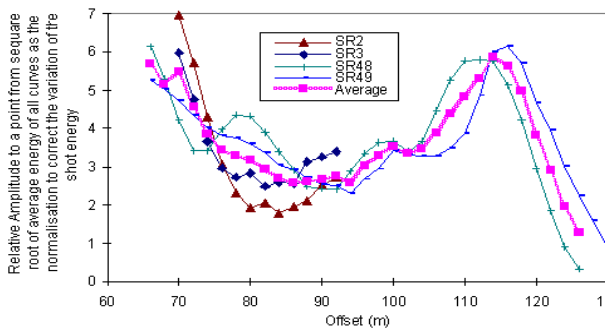
Figure 11.the curves of East-to-West shot (AveSR2&3) and the energy spectrum of most West-to East shot (SR48&49), both of them have deviation about 9 %

The AVO observation was carried out after the sequence of AVO processing similar to that of the Edwinstowe records. Figure 9 shows four AVO curves from both real data and mathematical models. Each involves lithological boundaries and water tables as hydrological boundaries from Croft and Edwinstowe records respectively. Each point has been normalized to the point at position of 28.2^o. This normalization will reduce the effect of the variation of the energy source, instrument gain, and the lateral variation of layer. Data lithology (Data-lit) has been taken from a super gather as a stack of 22 CMP gathers. Although individual CMP gathers do not give any trend, the stack from the CMP gather still gives representative curves that have decreasing amplitude with increasing offset. This evidence proves that the lithological boundary produces a negative AVO gradient.

The straight lines are the linear of four curves. We can see that both data and models of linear curves are joined at the point of 28.2 ^{o} but in different places, (the model is exactly at 1 and the data is at about 1.07). This is because the linear of model point is from of the data that has very a small variation, while the data point has a much wider variation. The slope of both Data-lit and Data-wt are also higher than both Model-lit and Model-wt, because the real data has more complex parameters than the model. The most important consideration is that the application of AVO analysis gives sufficient evidence that amplitude increases with increasing offset for water table reflection as a hydrological boundary for both the model and real data. Conversely, the amplitude decreases with increasing offset for sub-bedding reflection as a lithological boundary for both model and real data.
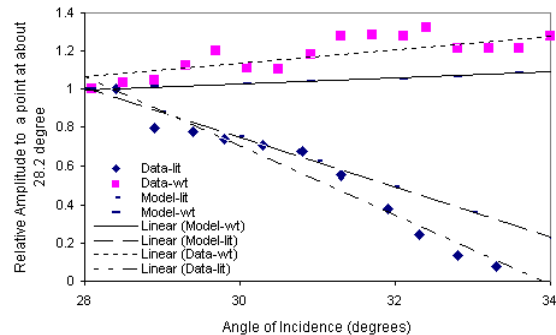
Figure 12.AVO analysis from mathematics model and observed data (Water table from Edwinstowe and lithology from Croft record) after conferted to angle of Incidence (degrees)

IV. Discussion

There are four points that we set this work in geophysical context.

1. We have shown that data can be collected with high enough quality to allow imaging shallow water table reflection.
2. We have further shown that AVO analysis of this data process a water table as liquid-surface reflector.
3. This is important as a continuing progressive in development of shallow reflection method, little additional field effort and additional processing time.
4. We note that there are two still problems;

a. Reducing coherent noise, to allow examination of sub-critical response.
b. Demonstrating separation of AVO response of closely spaced lithological and hydrological boundary.

V. Conclusion

The Croft data has specifications that are appropriate for application to the AVO analysis of lithological boundaries. The velocity structure of three simple layers is interpreted as geophysical interpretation, even if there is a high velocity (second layer) in the Croft data that is probably (1) Stocking ford shale's (Cambrian) or (2) Gypsum in the Mercian Mudstone (but not halite). Edwinstow seismic record presented the water table reflector as hydrological boundary

(Mustain, 2009, Mustain, 2010) was appropriate to be used to the comparation analysis .

The AVO curve shown in figure 9 establishes that the offset is also for post critical angles, which the critical angle at about 110m offset. As mentioned before, (Edwinstowe data) the focus of our AVO analysis is the post critical angle. Therefore, this figure is good evidence for both lithological and hydrological boundaries, and for mathematical models and observed data.

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Studi Kualitas Air Tanah di Pesisir Surabaya Timur

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Abstrak – *Kebutuhan air di kota besar semakin bertambah, tetapi ketersediaannya justru semakin terbatas, terutama di kawasan pesisir. Selain keterbatasan jangkauan infra struktur air bersih, kualitas airtanah yang tersedia di alam kemungkinan semakin tidak memenuhi kualitas karena pengaruh air laut. Makalah ini menyampaikan hasil studi kualitas airtanah di pesisir Surabaya timur, dengan tujuan untuk melihat potensi kemungkinannya sebagai sumber air bersih dan pemanfaatannya untuk perikanan air payau. Hasil studi menunjukkan bahwa, berdasarkan kualitas, hanya sebagian kecil di wilayah bagian barat daerah studi yang kandungan airtanahnya dapat digunakan sebagai air bersih tetapi tidak layak untuk air minum. Sedangkan semakin kearah timur atau kearah laut tidak dapat digunakan sebagai air bersih, tetapi potensial untuk dimanfaatkan sebagai sumber air untuk budidaya perikanan air payau.*

Kata kunci: *pesisir Surabaya timur, kualitas airtanah*

I. PENDAHULUAN

Ketersediaan air untuk air minum, mandi cuci dan kakus, serta untuk irigasi merupakan hal yang vital bagi kehidupan manusia. Bahkan ketersediaan air bersih merupakan salah satu parameter tingkat kesehatan, sekaligus tingkat kesejahteraan suatu masyarakat. Bagi Surabaya, sebagai kota metropolitan, ketersediaan air tidak terbatas untuk memenuhi kebutuhan warganya, tetapi juga untuk kebutuhan perkantoran, mall dan pusat perdagangan, perhotelan, dan industri, yang justru lebih besar jumlahnya dibanding untuk kebutuhan domestik. Kebutuhan air untuk kehidupan sehari-hari warga tidak dapat dipenuhi seluruhnya oleh Perusahaan Daerah Air Minum. Oleh karena itu sebagian penduduk memanfaatkan airtanah untuk memenuhi kebutuhannya. Akan tetapi, wilayah pesisir Surabaya timur yang relatif jauh dari jangkauan distribusi air minum justru memiliki airtanah yang mempunyai kualitas yang mungkin tidak memenuhi syarat untuk air bersih, karena pengaruh air laut (Wahyudi dkk., 2012).

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Studi pengaruh air laut terhadap kualitas airtanah di wilayah pesisir Surabaya timur telah dilakukan oleh Wahyudi dkk. (2012). Makalah ini menyampaikan hasil studi lanjutan terhadap kualitas airtanah di pesisir Surabaya timur, dengan menambah jumlah parameter kualitas airtanah yang dianalisis serta jumlah titik pengambilan sampel. Analisis dilakukan terhadap parameter kualitas air tanah yang meliputi temperatur, pH, salinitas, kandungan sulfida H_2S, nitrit, nitrat, amonia, dan fosfat. Analisis terhadap parameter tersebut telah dilakukan terhadap 70 sampel dan telah dipetakan distribusinya. Berdasarkan peta tersebut dapat diketahui kemungkinan pemanfaatan airtanah untuk budidaya perikanan ikan payau, serta pengaruh air laut terhadap airtanah dangkal.

II. Dasar Teori

II.I Airtanah dan Kualitas Air

Airtanah adalah air yang bergerak di dalam tanah yang terdapat di dalam ruang antar butiran tanah dan di dalam retakan batuan yang disebut juga sebagai air celah. Airtanah merupakan air yang mengisi pori

lapisan bumi yang berada di bawah permukaan air tanah (Sosrodarsono dan Takeda, 1993). Air tanah adalah semua air yang terdapat di dalam lapisan tanah atau batuan di bawah permukaan tanah pada zona jenuh air. Muka air tanah bebas atau muka freatik adalah muka air tanah pada akuifer tidak tertekan. Akuifer adalah lapisan batuan jenuh air di bawah permukaan tanah yang dapat menyimpan dan meneruskan air. Air tanah tidak tertekan atau air tanah bebas adalah air tanah yang terdapat di dalam akuifer tidak tertekan (BSN, 2005).

Kualitas air merupakan standar baku mutu dengan kriteria tertentu yang dibutuhkan dalam pemanfaatan air sesuai dengan peruntukannya. Kualitas airtanah ditentukan oleh sifat fisik dan sifat kimia air. Sifat fisik air antara lain temperatur, bau, dan kekeruhan. Sedangkan sifat kimia meliputi antara lain, salinitas, oksigen terlarut (DO), derajat keasaman (pH), kandungan ion, dan nutrisi airtanah yang antara lain NO_3-N, NO_2-N, NH_3-N, PO_4, dan H_2S.

Kriteria mutu air dan penetapan kelas air diatur pada PP No.82/2001, yang disertai dengan Lampiran Kriteria Mutu Air berdasarkan Kelasnya. Kelas air adalah peringkat kualitas air yang dinilai masih layak untuk dimanfaatkan bagi peruntukan tertentu. Kriteria mutu air adalah tolok ukur mutu air untuk setiap kelas.

II.II Kandungan Nitrit, Nitrat, Amonia, dan Phosfat Dalam Airtanah

Nitrit dalam air dapat berasal hasil reaksi oksidasi amonia oleh bakteri nitrosomonas. Keberadaan nitrit (N-NO_2) menggambarkan berlangsungnya proses biologis perombakan bahan organik yang memiliki kadar oksigen terlarut sangat rendah. Kadar nitrit di perairan relatif kecil karena segera dioksidasi menjadi nitrat. Di perairan alami, kadar nitrit sekitar 0,001 mg/L dan tidak melebihi 0,06 mg/L. Kadar nitrit yang lebih dari 0,05 mg/L dapat bersifat toksik bagi organisme perairan yang sangat sensitif. Nitrit meracuni ikan dengan mengikat hemoglobin dalam darah mencegah agar tidak membawa oksigen, pada dasarnya menyesakkan ikan. Insang ikan mati akibat keracunan nitrit dengan warna kecoklatan (OATA, 2008). Standar baku mutu nitrit untuk air minum Permenkes No. 416, tahun 1990 adalah tidak boleh lebih dari 1 mg/L.

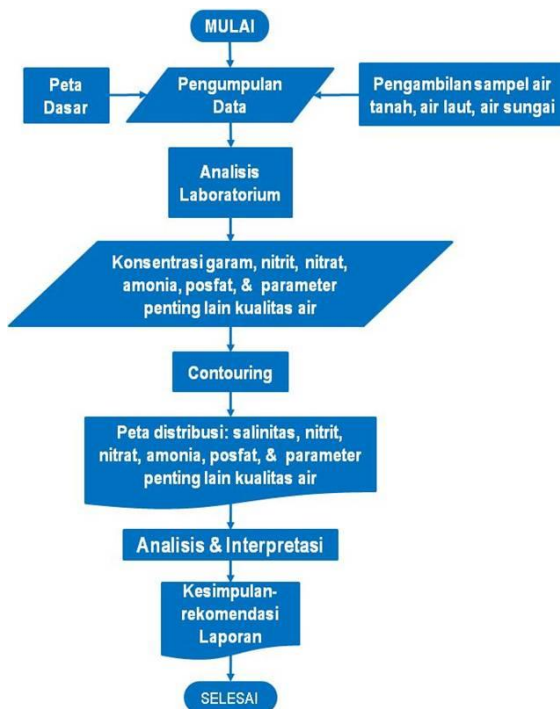
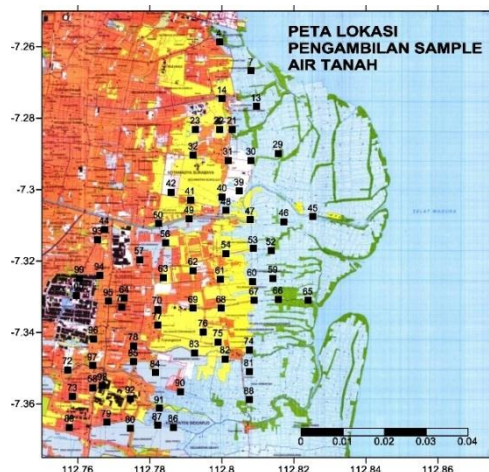
N-Nitrat sangat mudah larut dalam air dan bersifat stabil. Nitrat merupakan bentuk utama nitrogen dalam air dan merupakan nutrien utama bagi pertumbuhan tanaman dan alga (Bahri, 2006). Kadar nitrat di perairan yang tidak tercemar biasanya lebih tinggi dari amonia. Pada perairan yang kaya oksigen nitrogen cenderung berbentuk nitrat, dan sebaliknya nitrogen cenderung berbentuk amonia (Hutagalung & Rozak 1997). Kadar nitrat yang melebihi 5 mg/L menunjukkan terjadinya pencemaran antropogenik, misalnya masuknya limbah permukiman, industri atau limbah pertanian (pemupukan) yang umumnya banyak mengandung nitrat. Standar baku mutu air minum Permenkes No. 416, tahun 1990 adalah tidak boleh lebih dari 10 mg/L

Amonia merupakan hasil dari proses penguraian bahan organik akibat kotoran organisme dan aktivitas jasad renik dalam proses dekomposisi bahan organik yang kaya akan nitrogen. Biasanya dalam betuk amonia total yang terdiri dari amonia berion (NH_4) dan amonia bebas (NH_3). Amonia berion tidak beracun, sedangkan amonia bebas bersifat racun. Tingkat peracunan amonia berion berbeda-beda untuk tiap spesies, tetapi pada 0,6 mg/L dapat membahayakan (Boyd, 1982). OATA (2008): konsentrasi NH_3 > 0,2 mg/L menyebabkan ikan menjadi stres dan pada tingkat yang lebih tinggi menyebabkan kerusakan insang dan organ internal lainnya yang akan menyebabkan kematian pada ikan.

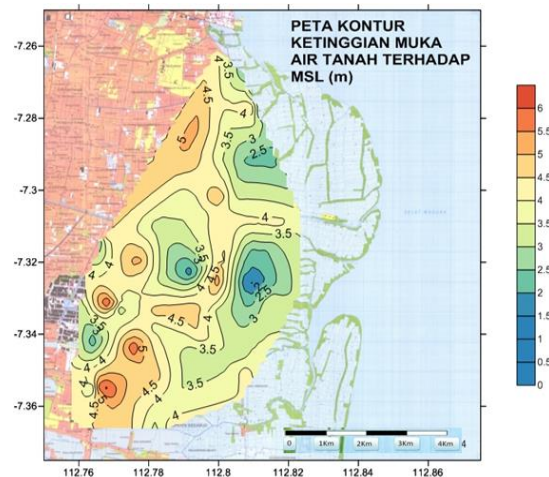
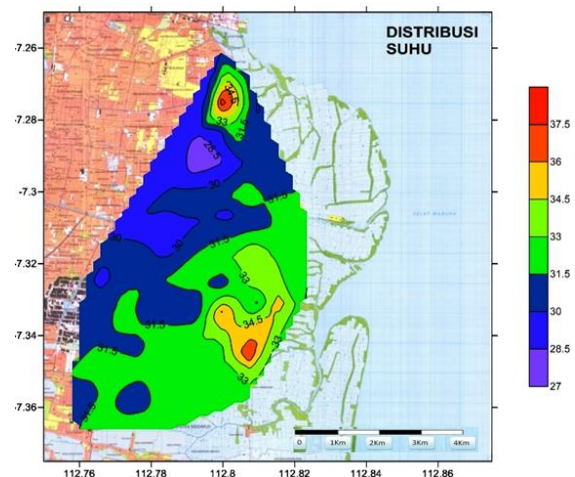
Fosfat adalah bentuk fosfor yang dapat dimanfaatkan oleh tumbuhan dan merupakan unsur esensial bagi tumbuhan tingkat tinggi dan alga sehingga dapat mempengaruhi tingkat produktivitas perairan (Bahri, 2006). Perairan yang mengandung fosfat tinggi kemungkinan telah mengalami pencemaran limbah organik dari permukiman atau dari industri. Ambang baku fosfat untuk budidaya ikan adalah 1 mg/L (OATA, 2008). Pada konsentrasi yang lebih tinggi menyebabkan kerusakan insang dan organ internal lainnya yang akan menyebabkan kematian pada ikan (OATA, 2008).

III. Metode Penelitian

Langkah penelitian diringkas dalam diagram alir dan disajikan pada Gambar 1. Penelitian ini dilakukan dengan mengambil sampel airtanah dari 70 titik lokasi di wilayah pesisir Surabaya timur (Gambar 2). Dalam pengambilan sampel air tanah digunakan peta dasar Peta Rupa Bumi, dan GPS untuk menentukan posisi, koordinat dan elevasi titik pengambilan sampel. Sampel air diambil dari airtanah di bawah permukaan tanah, dengan cara melakukan pemboran tanah dengan *auger hand bor* sampai mencapai kedalaman 50 cm sampai 100 cm di bawah muka airtanah (GWL = groundwater level).

Pada saat mengambil sampel air, dilakukan pula pengukuran secara langsung kedalaman muka air tanah, temperatur airtanah, pH, dan oksigen terlarut. Sampel airtanah yang diambil kemudian dianalisis di laboratorium untuk diukur kadar salinitasnya, konsentrasi sulfida-H_2S, Nitrogen-NO_2, Nitrogen-NO_3, Nitrogen-NH_3, dan PO_4.

Gambar 1.Diagram alir tahap penelitian

Gambar 2.Peta lokasi pengambilan sample airtanah

IV. Hasil dan Pembahasan

Secara geologi, pesisir Surabaya bagian timur merupakan dataran pantai dengan kemiringan sangat landai sampai datar, tersusun oleh sedimen aluvial, belum kompak sampai lepas, campuran pasir, lanau, dan lempung. Elevasi muka air tanah berkisar antara 0,25 m sampai 2,75 m di atas muka air laut (m.a.l). Secara umum elevasi muka airtanah semakin dangkal dan mendekati m.a.l kearah laut (Gambar 3). Dalam penelitian ini sampel airtanah dari pesisir Surabaya timur telah diambil dari 70 lokasi dan telah dilakukan pengukuran terhadap parameter kualitas air secara insitu maupun di laboratorium. Hasil pengukuran dari sebagian sampel disajikan pada Tabel 1 dan dari seluruh sampel disajikan pada Gambar 4 sampai 12.

Gambar 3.Peta elevasi muka air tanah (dalam m diatas m.a.l) di pesisir Surabaya timur

Gambar 4. Peta temperatur (dalam oC) airtanah di pesisir Surabaya Timur

Tabel 1.Sebagian dari hasil pengukuran sampel airtanah dari wilayah pesisir Surabaya timur

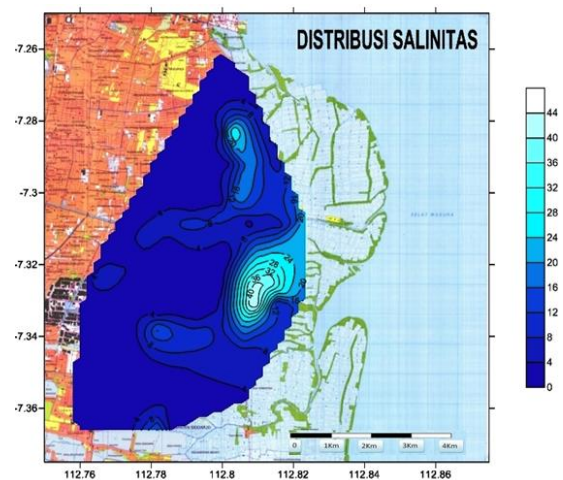
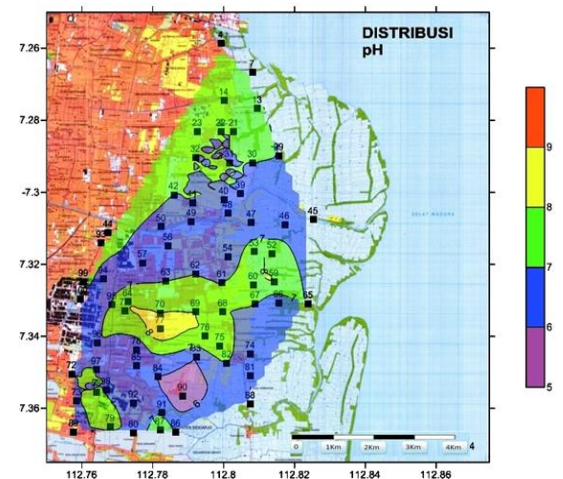
St	Kordinat (UTM)			GWL (m) di atas m.a.l	pH	DO	T (ºC)	Sali-nitas (ppt)	Sulfida H_2S (mg/L)	Nitrit NO_2-N (mg/L)	Nitrat NO_3-N (mg/L)	Amonia NH_3-N (mg/L)	Pospat PO_4-P (mg/L)
	x	y	Z (m)										
52	700189	9190788	4	2,41	8	2,99	32,9	25	0,00	0,000	2,51	17,11	1,41
53	699641	9190843	4	2,45	8	3,26	34,1	20	0,00	0,000	0,30	37,15	1,17
54	698837	9190691	5	4,7	6	2,93	32,8	0	0,00	0,040	0,45	2,84	0,40
63	696894	9189957	4	3,27	7	3,56	31,5	0	0,00	0,040	0,070	3,02	0,44
62	697825	9190168	4	1,67	7	3,83	32,8	2	0,00	0,000	0,03	7,22	0,30
61	698633	9189885	6	5,41	7	3,36	30,6	0	0,00	0,300	0,24	5,68	2,32
60	699610	9189840	4	1,25	8	4,52	33,5	42	0,00	0,000	0,12	31,06	2,91
59	700254	9189908	4	2,12	8	3,5	33,8	40	0,00	0,000	0,08	1,81	1,81
67	699673	9189261	3	2,31	7	4,3	30,9	47	0,00	0,020	0,09	17,27	0,64
65	701325	9189237	4	3,24	7	3,74	31,2	15	0,00	0,000	8,05	3,67	0,35

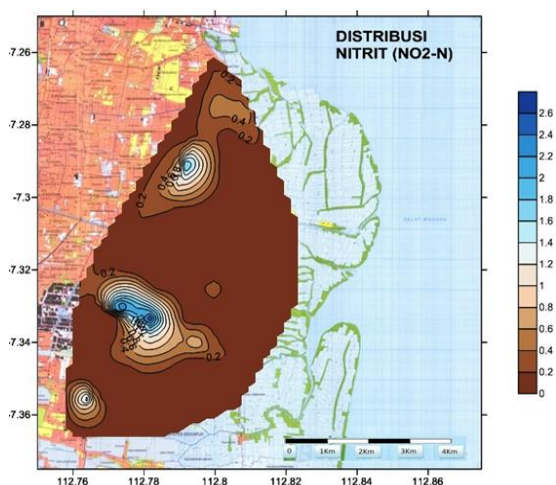
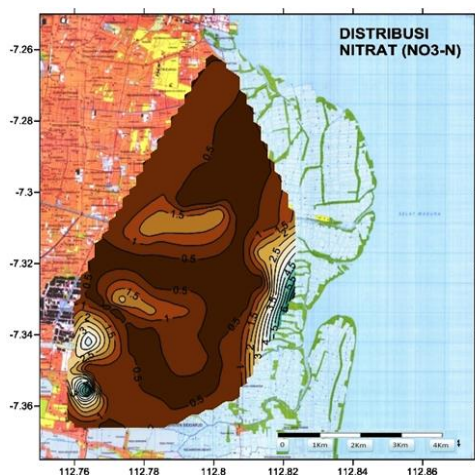
IV.I Distribusi Temperatur, pH, Oksigen Terlarut, Salinitas, Nitrit, Nitrat, Amonia, Sulfidan, dan Fosfat dari Airtanah di Pesisir Surabaya Timur

Gambar 4 menunjukkan distribusi temperatur airtanah, yang berkisar dari temperatur terendah 27°C dari sampel pada stasiun 32 dan tertinggi 38,8°C pada stasiun 14. Secara umum penyebaran temperatur airtanah menunjukkan semakin tinggi kearah pantai.

Secara umum kadar garam dalam airtanah semakin rendah kearah daratan atau semakin menjauh dari garis pantai (Gambar 5). Nilai kadar garam berkisar dari 0,2 ppt sampai 0,8 ppt ditemukan di bagian barat daerah studi. Semakin kearah laut kadar garam meningkat dari 2 ppt sampai 8 ppt di bagian tengah daerah studi, dan semakin kearah utara kenaikan kadar garam semakin tinggi pada kisaran 20-32 ppt di bagian timur laut pesisir Surabaya.

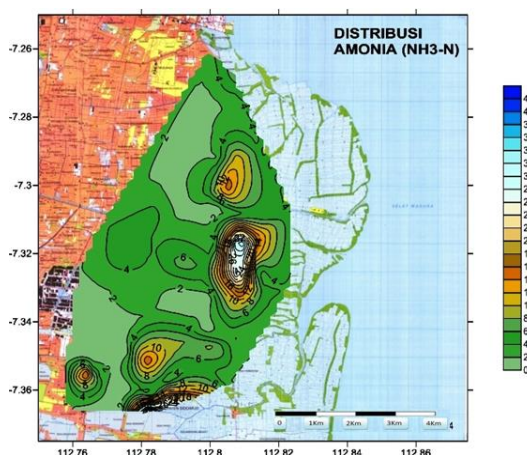
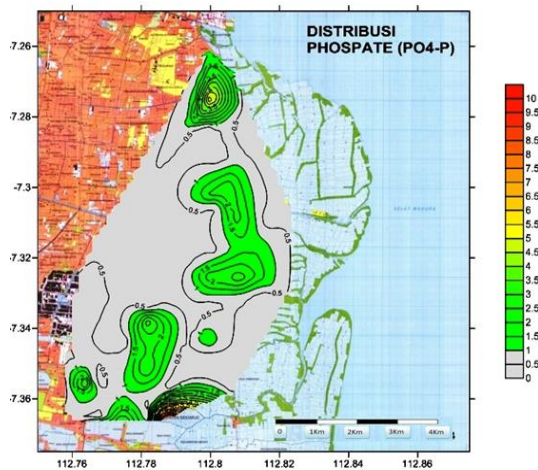
Airtanah di stasiun 67 di daerah Medokan Sawah timur memiliki salinitas 47 ppt, melebihi salinitas air laut. Kondisi ini diinterpretasikan karena airtanah yang ada merupakan *connate water* atau air formasi yang terendapkan bersama endapan sedimen laut. Berdasarkan kadar garam, airtanah di wilayah Surabaya timur tidak layak untuk air minum, tetapi aman untuk budidaya perikanan air payau.

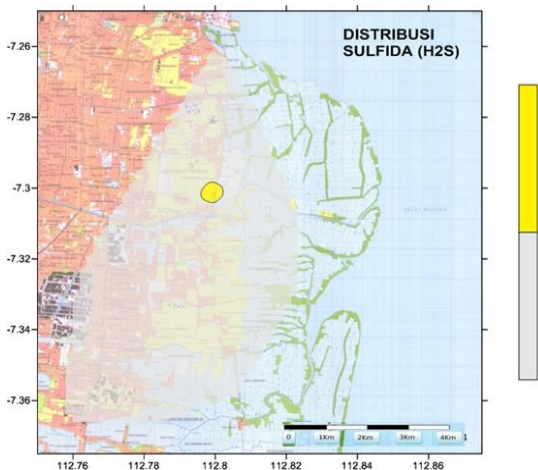
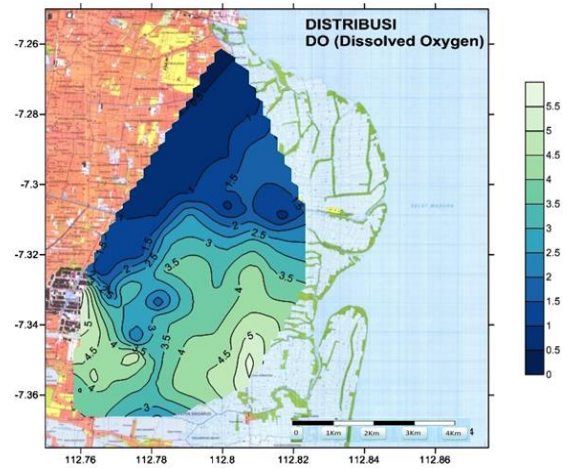
Distribusi pH airtanah di pesisir Surabaya timur berkisar antara 5 - 9 (Gambar 6). Nilai tertinggi pH 9 dijumpai pada stasiun 77, di daerah lapangan berdekatan dengan perbukitan Gunung Anyar yang banyak vegetasi. Reaksi aktivitas fotosintesis yang membutuhkan banyak ion CO_2 sehingga menyebabkan pH air tanah naik. Nilai terendah pH 5 dijumpai pada stasiun 90 yang berdekatan dengan tambak, di belakang perumahan Pondok Candra Indah Surabaya. Di titik ini banyak tanaman air sehingga respirasi CO_2 yang dihasilkan semakin banyak, hal tersebut dapat menyebabkan pH air tanah turun. Secara umum kualitas airtanah berdasarkan derajat keasaman di pesisir Surabaya timur layak untuk dikonsumsi sebagai air baku atau air bersih.

Gambar 5.Distribusi salinitas (dalam ppt) airtanah di pesisir Surabaya timur

Gambar 6.Peta derajad keasaman (pH) airtanah di pesisir Surabaya Timur

Gambar 7 menunjukkan distribusi konsentrasi nitrit (NO_2-N) airtanah di pesisir Surabaya timur, yang berkisar antara 0 - 2.67 mg/L. Kadar maksimum nitrit untuk penggunanan air minum adalah 1 mg/l dan untuk perikanan tidak boleh lebih dari 0,06 mg/l. Konsentrasi yang tinggi di stasiun 64 sebesar 2,67 mg/L di daerah Rungkut Asri, diinterpretasikan karena dekat tempat pembuangan sampah akhir, sehingga airtanah tercemar limbah sampah, limbah rumah tangga dan limbah industri. Kurangannya mikroorganisme yang bisa merubah bahan organik menjadi nitrat dalam proses oksidasi juga merupakan penyebab tingginya kadar nitrit.

Gambar 7.Kandungan nitrit (mg/l) dalam airtanah di pesisir Surabaya Timur

Gambar 8.Kandungan nitrat (mg/l) dalam airtanah di pesisir Surabaya Timur

Distribusi konsentrasi nitrat (NO_3-N) airtanah di pesisir Surabaya timur ditunjukkan pada Gambar 8. Konsentrasi terendah pada stasiun 30 dengan nilai 0 mg/l yaitu di daerah Keputih Lor depan Dian Regency, sedangkan konsentrasi tertinggi pada stasiun 65 di daerah Gunung Anyar Tambak. Kandungan zat organik yang tinggi, kandungan oksigen yang cukup dan juga proses penyimpanan sampel yang terlalu lama bisa menyebabkan tingginya kadar nitrat dan rendahnya kadar nitrit dan amonia.

Distribusi konsentrasi amonia (NH_3-N) dalam airtanah di pesisir Surabaya timur ditunjukkan pada Gambar 9, dengan konsentrasi antara 0 - 43,61 mg/L. Konsentrasi terendah pada stasiun 92, 79, 85, 97, 72, 100, 69, 96 dengan nilai 0 mg/L, sedangkan konsentrasi tertinggi dijumpai pada stasiun 87 dengan nilai 43.61 mg/L di daerah tanah kosong di kawasan perumahan peranti. Indikasi Tingginya kandungan amonia dalam airtanah di titik 87 mengindikasikan airtanah tercemar limbah atau pupuk, karena lokasi tersebut merupakan bekas sawah atau tambak yang diuruk. Airtanah di sekitar stasiun 87 ini tidak memungkinkan untuk di gunakan sebagai air minum.

Gambar 10 menunjukkan distribusi kandungan pospat (PO_4-P) airtanah di pesisir Surabaya timur, dengan konsentrasi 0 - 11,55 mg/L. Kadar fosfat airtanah tertinggi berada pada stasiun 86. Kadar fosfat cenderung tinggi di bagian timur dan dan juga di bagian selatan. Tingginya kadar fosfat menunjukkan tingginya limbah domestik dari permukiman yang berupa sisa deterjen, sisa sabun mandi, kotoran manusia dan juga sampah makanan.

Gambar 9.Kandungan amonia (mg/l) dalam airtanah di pesisir Surabaya Timur

Gambar 10.Kandungan phospat (mg/l) dalam airtanah di pesisir Surabaya Timur

Gambar 11 menyajikan distribusi kandungan hidrogen sulfida (H_2S) airtanah di pesisir Surabaya timur. Kandungan H_2S dalam airtanah hampir di seluruh stasiun pengambilan sampel di daerah penelitian di pesisir Surabaya timur adalah 0 mg/L atau tidak mengandung H_2S. Tetapi, ada satu sampel yang memiliki kandungan sebesar 2,08 mg/L yaitu di stasiun 40 dekat dengan TPU dan tambak yang hampir mengering di Sukolilo, Medokan Keputih. Tingginya sulfida pada stasiun 40 diinterpretasikan karena banyaknya pembusukan zat organik yang.

Gambar 11.Kandungan sulfida (mg/l) dalam airtanah di pesisir Surabaya Timur

Gambar 12.Distribusi kandungan oksigen terlarut (mg/L) airtanah di pesisir Surabaya Timur

Gambar 12 menunjukkan distribusi kandungan oksigen terlarut (DO) dalam airtanah di pesisir Surabaya timur, yang berkisar antara 0,73 mg/L - 6,00 mg/L. Konsentrasi terkecil dijumpai pada stasiun 48 dengan nilai 0,73 mg/L, di tanah kosong berdekatan dengan permukiman daerah Wonorejo. Konsentrasi tertinggi dengan nilai 6,00 mg/L dijumpai pada stasiun 100 di daerah Rungkut Industri.

Kandungan oksigen terlarut dalam airtanah yang rendah menunjukkan banyaknya kebutuhan oksigen untuk menguraikan zat organik dalam airtanah. Kandungan DO airtanah di daerah studi cenderung rendah, karena kondisi airtanah di daerah dekat pantai yang merupakan daerah akumulasi limbah organik serta daerah pesisir perkotaan yang padat permukiman yang banyak membuang limbah organik, sehingga kandungan oksigen dalam airtanah rendah.

Kesimpulan

Berdasarkan analisis dan interpretasi data yang diperoleh dapat ditarik beberapa kesimpulan seperti di bawah.

1. Pola sebaran temperatur, keasaman, konsentrasi nitrit, nitrat, amonia, fosfat, oksigen terlarut, dan sulfida dalam air tanah di pesisir Surabaya timur tidak berhubungan dengan pengaruh air laut. Tidak ada kecenderungan semakin dekat dengan garis pantai semakin tinggi konsentrasi.
2. Hanya sebagian wilayah kecil di bagian barat daerah studi yang kandungan airtanahnya dapat dimanfaatkan sebagai sumber air bersih, dan sebagian besar airtanah di wilayah pesisir Surabaya timur tidak layak untuk air minum.
3. Sangat mungkin dilakukan budidaya perikanan air

payau di pesisir Surabaya timur dengan memanfaatkan air tanah.

4. Tidak ada pengaruh intrusi air laut terhadap air tanah.
5. Pengaruh air laut terjadi karena masuknya air laut pada saat air pasang dan kemungkinan permukaan air tanah bebas berhubungan langsung dengan permukaan air sungai yang bercampur dengan air laut.

Ucapan Terima Kasih

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Impact Of Topographic Change Against Groundwater Recharge Areas Caused By Limestone Mining In Rengel District, Tuban Regency

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Abstract – *Exploitation of limestone in Tuban Regency has been carried out continuously with a very large amount of production. In one area of 12 hectares mining site alone can produce more than 290.000 tons per year, this condition leads to significant change in the topography of the mining area. In this study, research was conducted to the impact of changes in topography, which results to the change of broad, shape, and the ability of water recharge areas that lead to the groundwater reserve. The primary data used is the amount of mined limestone produced by PT. Pentawira in researched site and DEM (Digital Elevation Model) satellite imagery. In addition, the supporting data used are characteristic of limestone and the reserve data of groundwater in Tuban Regency. Analysis of DEM satellite imagery, presents the model of geomorphology and topography of the study area, and then combined with mining data provided by PT. Pentawira to create a model or simulation of topography changes in the mining site, and how much impact it produce to the groundwater recharge areas including the reduce ability of recharge areas in the research site to absorb meteoroids water, that it is known after conducting the research that from 2013 forward the absorbance ability is reduced to more than 31 million liters per year. The analysis result of the study in this research can be used as a reference for the government in arranging environmental impact assessment for limestone mining companies. Mining activity will be controlled if the environmental impact assessment is done correctly, so that both environmental balance and sustainability can be maintained. The research site was conducted in Rengel District, Tuban Regency, East Java.*

Keywords: *Digital Elevation Model; Groundwater; Limestone; Recharge Area; Topography*

I. Introduction

I.I Background

Lithological conditions and geography Tuban most of the land in this area is composed of limestone. Although the topography Tuban is low, the area has reserves of underground water which is quite large. Groundwater recharge areas close association with (recharge area). Recharge area is very important because whether large or groundwater reserves are affected by the additive. Groundwater flow is always associated with the topography of an area (Shiklomanov & Rodda, 2003).

Mining limestone almost done throughout the district in Tuban district, one in the District of Rengel. Impact on the topography of the mining is changed to lower. In this study, observations were made in the district Rengel, Tuban. The intent and purpose of this research is to make an analysis of the influence of topography changes due to mining on groundwater recharge areas. The result is expected to be a reference for the various parties to perform activities related to the mining of limestone and underground water usage in order to maintain environmental sustainability.

I.II Tuban Regency

Tuban regency is located at 111 ° 30' - 112 ° 35 'E 6 ° 40' - 7 ° 18 ' South Latitude. Ground state in Tuban consists of mountains derived from limestone deposition in the hill to the mountain peaks contained in sub Semanding, Montong, Hoists, and Plumpang. Derived from alluvial sediments in the plains and basins are in District Rengel, Tambakboyo, Soko, and Cross. Grumusol sediments derived from the undulating rocks in the area are in Banjar district, Jatirogo, and Senori. Potential mineral limestone quarry (limestone) in Tuban scattered in several

locations limestone mountains Tuban. Potential limestone deposits are estimated at ± 1.089.531.362 tons. From these data, which has been done is the exploitation of ± 86,175,962 tons. Production of limestone mostly utilized by PT. Semen Gresik cement as raw material and PT. Pentawira as mature limestone (Ministry of Energy and Mineral Resources Replubic Indonesia, 2010)

II. Methods

The research was conducted in accordance with the research process. After the identification and formulation of the problem and determined the research area, data collection of sample and characteristics of limestone, the mining data, DEM and Citra satellite in research location.

The first data collection was a limestone sample data. Limestone samples which the main mining products in Tuban were taken to measure its density because the characterization of limestone is different in each region. The tools that used in this research are beaker glass to measure the volume of limestone and analytical balance to weigh its mass. Density measurements made with the mass of limestone sample per volume as indicated in following equation.

$$\rho = \frac{m}{V}$$

- ρ = density (gram/cm3)
- m = mass (gram)
- V = volume (mL)

The density values used to determine the amount of water that can be absorbed by one ton of limestone. After it, using the amount of water absorbed by one cubic meter of limestone and conversing in tones used limestone density as shown in following equation

$$Qw = m \times \rho \times k$$

- Qw = the amount of water absorbed per one ton of limestone (liter/ton)
- m = mass (ton)
- ρ = density (gram/cm3)
- k = the amount of water absorbed per cubic meter ;150 liter/m3, (ESDM Bandung, 2010)

The amount of water that can be absorbed by the limestone used in calculating the reduction of the limestone and the ability of water recharge area in absorbing every years using the effective day of mining or production activities as well as combined with mining production data, use following equations.

$$Dp = Dt - Dn$$

- Dp = the amount effective days in one year (days)
- Dt = amount of days in a year (days)
- Dn = the amount of non-productive days (days)

$$QLt = QLD \times Dp$$

- QLt = amount of limestone mined during one year (tons)
- QLD = the average amount of limestone mined in one day (tons)
- Dp = the amount effective days in one year (days)

$$Qh = Qw \times QLt$$

- Qh = The amount of water lost per year (liters)
- QLt = Amount of limestone mined during a year (tons)
- Qw = the amount of water absorbed per one ton of limestone (litre/ton)

Modeling changes in topography and water recharge areas due to mining using Citra satellite DEM, coordinate data that took from positioning in the mining location, the reduction of limestone and water recharge areas data. The software that used in processing data is Global Mapper 11. The first step is plotting the coordinates on the mine site to the Citra satellite through Global Mapper 11. Then determined the parts and the boundary mine site. Last, by using the "3D Path Profile / Line of Sight Tool", obtained cross-sectional two-dimensional (2D) and the volume of mine sites. Changes in topography due to mining using a 2D cross section, mine site using Photoshop CS 3 software, so we get a comparison of the topography before and after limestone mining.

III. Findings

Mining activities affecting the factors that influence the formation of ground water, which reshaped the topography of the catchment areas and reduce the volume of waste rock in the unsaturated zone which is the first seep water zone before heading saturated zone and become the groundwater. Decreased volume of the waste rock will make the unsaturated zone become thinner and make the distance of saturated zone closer to the surface. The impact is that the water absorbs in unsaturated zone is reduced and also impact on increased run-off or surface water. This situation can be seen in the rainy season, where the discharge of water flowing in the

rivers near mine sites increasing drastically when compared to normal condition. Increased river flow is affected by the increasing number of surface water (run-off) from rain which is not absorbed in the unsaturated zone.

From limestone samples that have been taken from the research site, the result is limestone density measurements. The limestone sample had a volume of 0.1 liters with a mass of 0.225 kg. So the limestone sample density in Rengel District is 2.25 kg / liter.

Based on production data mining conducted by PT. Pentawira in District Rengel, Tuban regency in April 2013, were analyzed the average mining production per day is equal to 1,331.28 tonnes consisting of limestone and pedle (material derived from limestone mountain avalanches). Production of limestone and pedle 465,948 tonnes per year.

Mine site is located on a limestone mountain impacting many holes and giant basin on the mountain as an indicator of changes in the topography of the site.

Based on DEM data satellite, note that the study site was at an elevation 90 meters to 160 meters above MSL (Mean Sea Level), based on topographic data, it can be analyzed that the infiltration areas and recharge areas that are among the sites play a vital function in the hydrogeology cycle, particularly as recharge areas.

Based on the DEM data processing obtained widespread mining area is 12.11 hectares and more than 160 meters elevation above MSL. Volume of limestone deposits in diameter at 389 meters the area is 4,666,046 m3. Based on the mass conversion of limestone in one ton to cubic meter, using the method of determination of the absorbed water per ton of limestone, it can be seen that 1 ton of limestone can absorb 66.6 liters of water.

IV. Discussions

If in 2013, the volume limestone deposits in research site reached 4,666,046 m3 and mined of ± 1,331.28 tons / day, the meteoroids water that cannot be absorbed by the limestone decreased 31,032,136 liters / year. Simulation calculations for the next five years (assuming a constant number of mining), then in 2017 district Rengel will lack 155,160,684 liters of water infiltration caused by mining in *Figure 6 Modelling changes in topography due to limestone mining)* shows a comparison of the topography before and after mining, which shows that the topographical changes that occur significantly aided by the existing analysis and calculation. The topography changes one location, where it will certainly affect the groundwater depletion.

Based on the analysis and calculation of limestone loss due to mining, resulting in changes in topography are modeled based on the visualization of 2D cross-sectional image of the DEM satellite research sites. Modeling (see also affect recharge areas in the region, especially in terms of form and its ability. Recharge area ability to absorb water in the study area calculated will be reduced 31 million liters every year because of the impact of changes in the topography.
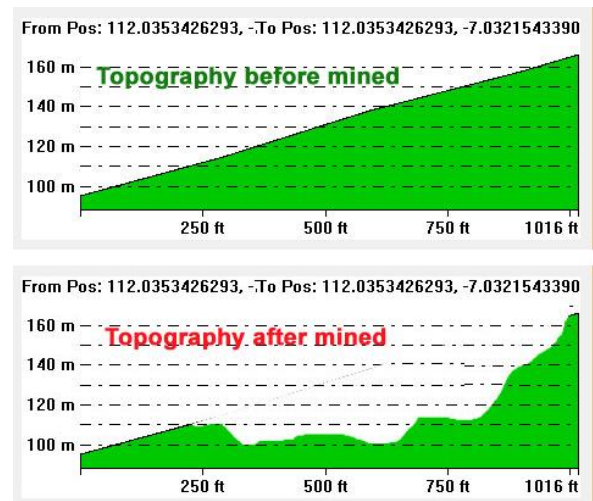
Fig 5.Modeling changes in topography due to limestone mining

In one year alone that the District Rengel had water loss (loss of potential water absorption) in large enough quantities. If this continues in the next 5-year period, the availability of underground water reserves District Rengel will be reduced and the impact it had on the community in the area around the District Rengel is the difficulty in obtaining underground water. Mining limestone mining causing changes in the topography of the area, thus reducing the amount of groundwater reserves.

V. Conclusions

Exploitation of limestone mountains in the district Rengel, Tuban affect the topography of the area and can reduce the amount of water reserves that exist in the recharge area. From the analysis and calculation of the data, it was found that the District Rengel loss of water absorption potential of 31,032,136 liters every year. If calculated over the next 5 years, the district Rengel water absorption potential loss of 155,160,684 liters of water. It can turn off the water source if mining is done without control and can detrimental to the community around the district Rengel because most of the the community use water from wells.

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Adaptations to Drought in Lamongan Municipality

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Abstract – *Lamongan Municipality suffered from drought which damaged 12,519 hectares/year from 2004 to 2011. The drought caused failure to paddy harvesting and limited clean water supply. The Current adaptations are only prioritizing and reducing water use. In addition, changing on farming method is one of the adaptations as well. These adaptations are inadequate to decrease the impacts of drought. Thus, this paper proposes effective adaptations to drought in Lamongan. To propose effective adaptations, we analyze potential drought areas in the municipality by using overlay and a raster calculator in ArcMap based on SPI Value. Afterward, we assess current adaptations by using Guttman scale to 100 respondents. Finally, we propose effective adaptations for every stage of disaster risk management cycle by using descriptive analysis. 15 out of 27 regencies in Lamongan Municipality suffer from the moderate drought. In total, those areas cover 15,107.9 hectares. The analysis of Guttman scale identifies that the current adaptations are in a reactive form of responses. As a result, we propose some effective adaptations which include selecting paddy seeds, providing economic incentives for water use reductions, and activating community savings as well as community friendly EWS (Early Warnig System).*

Keywords: *Drought, Effective adaptations and Current Adaptations*

I. Introduction

I.I Background

Drought is a natural hazard as a result of a precipitation shortage from expected rain over a season or longer, which is insufficient to meet the demands of human activities and the environment (Wilhite, 2005). The Characteristic of drought is quite different from other natural hazard, because it comes suddenly and is ignored easily. The impact will be seen when the productive land, such as agricultural crop, fails or decreases in quality. The other extreme impacts include the destruction of land due to not optimal land use system, famine, and destruction of agricultural systems.

The drought in Lamongan Municipality during the past decade has affected approximately 12,000 ha (Database of National Agency Disaster Management, 2011). Government of Lamongan Municipality mentioned that drought's impacts to farmlands are crop failure and water crises in widespread areas. Regional disaster management agencies of Lamongan recorded as many as 69 villages in 13 districts have clean water crises. The districts that are suffered from drought are Deket, Turi, Sukodadi, Pucuk, Lamongan, Sarirejo, Kembangbau, Karangbinangun, Tikung, Kedungpring, Sambeng, Modo, and Glagah District.

The impact of drought will get worse because of climate change in Indonesia is expected to increase in intensity. National Council on Climate Change (NCCC) said that Indonesia will experience a decrease in rainfall in the South region and on the contrarily, the North region will experience an increase in precipitation (National Action Plan on Climate Change Adaptation Indonesia, 2012).

The phenomenon of drought and its negative impacts are one of the main issues in spatial planning and

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closely related to global climate change. The report of IPCC working group IV (Inter-Governmental Panel on Climate Change/Intergovernmental Panel on climate change), recommends the study of disaster risk as a tool in assessing adaptation to disasters caused by climate change (Wilson & Piper, 2010).

Therefore, such effort is required to improve standard of living in the affected areas through proposed effective adaptations to drought by reducing the impact of disaster losses. To proposed effective adaptations, this paper will focus on the assessment of drought and evaluation of current adaptations in minimising the impacts of drought. Afterwards, this paper will propose adaptations to fill the gap of current adaptations in minimising the impacts of drought.

II. Findings and Discussion

II.I *Drought Severity*

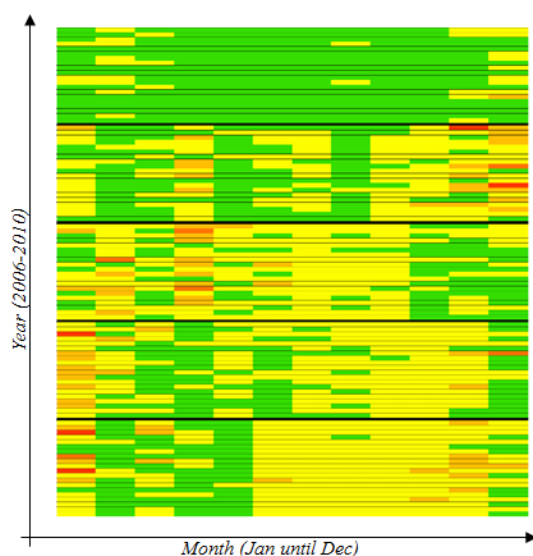
From the calculation of the SPI, in 2006 to 2010, the area was dominated by level of drought intensity at mild conditions. More details can be seen in the Figure 1.

The index reached its worst drought index value in -2.31 which stated that it has reached extreme drought. While the lowest value reached -0.098 that included dry to mild.

Table 1.Illustration of the distribution of droughts based on the SPI Values

II.II *Mapping Drought*

SPI has been used to quantify the precipitation deficit periods from 1980 to 2010. However, in this study, we used map for the period of 2006 to 2010 due to lack of the available data. the Drought map was a result from interpretation of SPI values in color gradation. In 2006, the average occurrence of severe drought occurred in the southern region of Lamongan, and also spread to other areas. Severity level for year 2006 based on the SPI value reached -2 which was categorized into extreme drought. The average distribution of drought in 2007, the spreading crept towards the middle of Lamongan, but with a decreased level of drought below -1, which included into mild drought.

The distribution of drought that occurred in 2008, showed that the average drought spread towards the center and north, while the south tended to be relatively dry. Drought level was relatively low for the year 2008 in which the classification fell in the mild category of -0.6. In 2009, distribution of drought spread more evenly, with the range covered almost the entire area, but was less dry than previous year, which was only -0.4 of mild drought. For distribution that occurred in 2010, occurred evenly, almost the same as in 2009, but the movement patterns of drought in 2010 (which occurred in the northern area of Lamongan) showed a decreasing level of drought. The level of drought by 2010 fell in the category of mild with a reduction of drought from 2009. From the above SPI analysis each year, the study then conducted an overlay analysis to obtain the distribution of the average area experiencing drought occurrence. Areas of potential risk of drought are shown in the following figure.

Based on the distribution of drought above, there were some districts that could potentially be at risk of drought. Some of these districts included Lamongan, Deket, Karangbinangun, Turi, Sukodadi, Kembangbahu, Glagah, Sukorame, Ngimbang, Blubuk, Modo, Kedungpring, babat, Sekaran, and Laren district.

II.III *Duration and Frequency of Drought*

The drought duration in this study was based on level of rain data which was calculated by using SPI. By looking at the SPI values on frequency and duration of drought in Lamongan, the study would be able to interpret the spreading. The longest drought duration reached 11 months. Meanwhile, the duration at most was 9 months, with the total of 13 occurrences happened in 5 year period of all station. Most of the highest drought hit 3 occurrences, with the total of 28 occurrences in 5 year period of all station. The lowest

drought hit 1 event, with the total of 6 occurrences in 5 year period of all station.

Based on the above duration and frequency of drought, the scenarios used in this study would be chosen from the worst occurrence in Lamongan Municipality. That event would be, if the longest duration of 9 months/year with the total of 3 occurrences/year has occurred.

II.IV *Current Adaptation*

Potential drought adaptations in this study area was divided into four categories by using the disaster management cycle approach, that are; response, recovery, mitigation, and preparedness. This was achieved by measuring some aspects such as, food water supply, water saving, etc. The assessment on the drought's adaptations was measured by Guttman scales to 100 respondents.

Based on a survey conducted, the responses to drought in the study area were as follows: recovering clean water, reducing and prioritizing water use. (1) Supplying clean water for drought affected communities. (2) Reduction in water use was divided into two categories, these were reduction for households and reduction for agricultural. (3) Priority in water use was divided into two categories as well, priority for households and for agriculture.

Recoveries to drought in the study area in facing drought, among others, were: managing irrigation for agriculture, the availability of catchment surface, and the availability of clean water network. (1) The management of irrigation networks in accordance with the needs of the agricultural area where the study area also had irrigation networks serving nearly 80 percent of the population. (2) Catchment surface in the study area included a small reservoir, as well as ponds spreading all over the study area. (3) The availability of clean water network in the study area had not spread evenly.

Mitigation efforts undertaken in the study area were divided into several types, such as water use and adjustment reserve fund / insurance. (1) There were adjustments of water use, which some efforts were also made, for example changing the agriculture planting schedules / crop, adding supplies, and reducing the needs. (2) The reserve fund / insurance had not been carried out completely by the drought affected communities.

Preparedness already existed in the study area, among others was, information and schedule planting season. (1) Information about the season that was known by more people was based on personal experience and observation. (2) Planting schedules were obtained from agricultural extension workers and farmers of the community.

II.V *Proposed Adaptation*

The proposed adaptations in this study focused on decreasing the immediate effects of drought once the phenomenon had occurred and restoring the affected areas to their previous state. These proposals to drought were based on the study through a descriptive qualitative analysis that combined some information /sources such as existing condition of drought impacts and triggers, drought-related policy issues, and drought-climate change adaptation studies. These main proposals were based on the disaster management cycle approach, as follows:

- Increase response for water supply. Response to drought in the study area had been carried out, where the results of measurements of current adaptation was considered capable of minimizing the hazard of drought. However the response of clean water supplies for drought affected communities was still not achieved evenly, this was mainly due to inadequate facilities, such as limited water carrier truck/fleet to distribute a fresh water when the drought came. The proposed adaptations to increase the response for water supply in Lamongan Municipality were divided into reactive and proactive responses, namely: (1) Reactive responses are; using unconfined aquifer, creating community cohesiveness in managing water-use; and (2) Proactive responses are; reducing water use to 5-10%, building damns/ ponds, supporting economic incentives for reducing water use, conducting water analysis, prioritizing water use
- Increase recovery after the drought time. The recovery efforts made during or after the drought were in the form of increasing the cover of green area (even though it was not too effective), functioning the irrigation networks and water patch, and recovering the clean water networks. However the supply of irrigation networks and the provision of clean water networks were not optimal. The proposed adaptations to increase recovery efforts were divided into rehabilitative and reconstructive recoveries: (1) Rehabilitation responses are; rehabilitating catchment areas, maintaining the drainage system including water storage (ponds), advancing the technologies in farming, integrating the irrigation and water storage (ponds); and (2) Reconstruction responses are; providing water through cooperation with HIPPAM (community based water management), building additional water storages, providing savings to face next drought,
- Increase mitigation on the area. Mitigation efforts in the study area were about the lack of availability of funds for drought losses, the early harvest time and buying clean water to

compensate the drought losses, and adjusting the planting crops during drought. There were several options to increase the mitigation efforts in Lamongan Municipality are; (1) Allocating reserve fund and creating a union for savings and loan; (2) Stabilizing the agriculture price by the government by buying the crops; and (3) Adjusting the planting system during the drought by changing certain crops that could tolerate drought.

- Increase preparedness. In the study area, the preparedness was done only by 36.48 percent. This condition lead to a proposal of creating an Early Warning System that would be easy to access by the community.

III. Conclussion

The drought in Lamongan Municipality had 3 characteristics: mild, moderate, and no drought. Most of the area in the municipality experienced mild drought with a total area of 105,799.8 Ha while the moderate drought area reached 15,107.9 Ha that consisted of 15 districts. From the analysis, the number of drought occurrence varied ranging from 1 occurrence, up to 5 occurrences. While the longest drought in Lamongan district was 9 months in a year. The drought intensity based on SPI index was -2.309 the highest (extreme drought) and -0.-98 the lowest (mild drought). Drought provided considerable adverse impacts to the community and other sectors such as water shortages. Identification of adaptation to drought was performed in the study area and produced that:

- Response: reducing household's water usage, prioritizing needs of the household, and supplying clean water.
- Recovery: an increase in green areas had not been effectively carried out to increase the availability of soil water, irrigation networks and catchment surface were available, and the provision of water supply network had not been achieved with the availability of the network only reached 37%.
- Mitigation: majority of the respondents did mitigation efforts, and the reserve fund for the public was not fully allocated for drought.
- Preparedness: preparedness in the study area had been carried out because the information about the characteristics of drought was available.

Due to those current adaptations, the study finally proposed some adaptations to minimise the adverse impacts of drought in the study area which were divided into 4 categories of disaster risk management, namely: (1) adaptations to increase response (including; supporting economic incentives for the actions on water use reduction); (2) adaptations to increase recovery (including; providing water through the cooperation with HIPPAM), (3) adaptations to increase mitigation (including; providing community savings and loans), and (4) adaptations to increase preparedness (including; building community friendly EWS (early warning system)).

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10 Sea Level Rise Flood Zones: Mitigating Floods in Surabaya Coastal Area

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Abstract – *Sea level rise (SLR) brings with it a negative impact towards Surabaya's coastal area as this particular part of the city is situated only 0-3 meters above sea level. The amount of damage due to the floods indicates the city's level of readiness in facing threats from the flood. With flood height up to 90 centimeters, it is necessary to classify flood risk levels in an attempt to reduce the impact that will occur. This paper identify sea level rise by using least square regression, which generates the trend and prediction of sea level rise. The next analysis is the identification of a potentially disaster due to sea level rise by using multinomial logistic regression. Identification of flood hazard characteristics through weighted-overlay analysis using flood height and duration as variables. It also identifies factors influencing vulnerability using Delphi analysis. AHP Expert is then employed to calculate the weight of each factor. Vulnerable zones are determined using overlay-weighted-sum on each vulnerable factor. These results are then mapped using Raster Calculator method, placing emphasis on risk functions influenced by hazard and vulnerability. The final result is a flood risk zone map which identifies 5 risk levels according to the National Disaster Mitigation Guidance.*

Keywords: *Sea Level Rise, Mitigation, Risk Zone*

1. Introduction

The increase of human activity, especially in the transportation, industry, building construction and human activities affect global climate change marked with an increase in Earth's average temperature from year to year. Based on research by WWF, Indonesia has an increase in temperature by 0.3 ° C since 1990 and climate change scenarios conducted by WWF Indonesia and the IPCC reported that the temperature will increase by 1.3 ° C to 4.6 ° C in 2100 with the rate by 0.1 ° C to 0.4 ° C that will lead to the sea level rise by 20 - 100 cm in 100 years. The rising of sea level (sea level rise) causes some islands and places lower than sea level in potentiall disaster, which is the fact that in coastal areas.

Surabaya, the second largest city in Indonesia as well as the capital of East Java province, is coastal city that has a delta system in coastal morphology and topography is located on low (average 0-6 meters above sea level) with an average slope <3 % (RTRW Surabaya). P3O-LIPI investigators (1991), meiviana et al (2004) in Proceedings of the National Seminar on Serealia (2009) and workshop proceedings (2010) showed the rate of sea level rise on coastal Surabaya as high as 5.47 mm per year, calculated in the period of 64 years (1925-1989), where the presence of sea level rise brings up the height of tide gauges. Based on data BMKG Maritim Tanjung Perak, Surabaya city was flooded due to the tide height between 150-170 cm above sea level. The followig impact due to sea level rise are the changes of coastal conditions, the increased erosion, the faster the damage to the buildings and the disruption of people's activities such as housing, industry, agriculture and others. Generally the extent of the damage occured will depend on the level and type of area edge of water used (UNDP, 2007).

2. Overview of Floods in Surabaya Coastal Area

Surabaya is located in south latitude and east longitude between 7○12' s.d 7○21' South latitude dan

112○36' s.d 127○54' east longitude. The study area is sub-districts located in the Coastal city of Surabaya. Based on data from the Maritime BMKG Surabaya, 2011 The average maximum height of tide in coastal areas Surabaya is 150-170 cm above sea level and shows a significant rise of sea level rise in surabaya approximately 4.8 mm / year. Here is portraits of flooding due to tides in coastal areas Surabaya.

3. Analysis

Preparation of the risk zone map is one of the mitigation as a result of non structural sea level rise so as to position the community at different levels of risk. here are the steps in the formulation of the risk zone.

3.1. Identification of Sea Level Rise

From the results of tidal analysis based on data per hour tidal Bakosurtanal of 20 years, with a datum Tanjung Perak Surabaya, dated January 1, 1984 to 31 December 2004 Surabaya tidal conditions are included tidal mix-leaning daily double (mixed tide prevelailing semidiurnal tide) which occurs twice a day ,twice as a high tide and twice as a low tide, but has a different height and periods. This type of tidal maters occurs a lot in the eastern Indonesia obtained predictions of sea level rise trend,as follows:

Table 1. Prediction of Trend Sea Level Rise

No	Tides	Trend of Sea Level Rise	Sea Level Rise (mm/years)	Positions of Sea Level Rise (m)			
				2010	2050	2080	2100
1.	MSL	Y= 1.49737+0.0003x	4 mm/th	1.558	1.732	1.84	1.912
2.	M2	Y = 0.3158+0.0001x	1 mm/th	0.3471	0.3962	0.4311	0.455
3.	S2	Y= 0.3158+0.0001x	4.8 mm/th	0.325	0.515	0.659	1.038
4.	HHWL	Y=2.8308+0.0004x	4.8 mm/th	2.956	3.148	3.292	3.388

Source : Analysis Result, 2012

Table 2. Prediction of Sea Level Rise until 2100

No	Tides	Trend of Sea Level Rise	Sea Level Rise (mm/years)	Positions of Sea Level Rise (m)			
				2010	2050	2080	2100
1.	MSL	Y= 1.49737+0.0003x	4 mm/th	0.094	0.238	0.346	0.418
2.	M2	Y = 0.3158+0.0001x	1 mm/th	0.031	0.080	0.115	0.139
3.	S2	Y= 0.3158+0.0001x	4.8 mm/th	0.125	0.317	0.461	0.840
4.	HHWL	Y=2.8308+0.0004x	4.8 mm/th	0.125	0.317	0.461	0.557

Source : Analysis Result, 2012

The trend of sea level rise above, shows an increase in sea level rise of 4.8mm / year. This can result in a serious danger because the topography is quite low in ranges from 0-3m above sea level.

3.2. Identification of a disaster due to sea level rise

The analysis phase is aimed to look at the influence of sea level rise on society and explain whether the disasters arereally occurred or not in the study area. This analysis uses the research variables consisting of two variables, namely the response variable (Y) is the flood due to sea level rise, sea water intrusion, and erosion caused by waves piling up water. and the predictor variable (X), the drainage network disruptions, the damage to the coastal environment, and an increase in mass of sea water. Here are the steps to find out the disasters caused by sea level rise on coastal areas Surabaya:

Validity test is used to test the suitability of the variable with the attributes of the questionnaire prior to analysis, data are grouped based on the criteria of each question. Here is a validity test result data:

H0: The data has a relationship
H1: Data not related (independent)
H0 is rejected if the correlation is less than 70%

Table 3. Output Validity Test

	P1	P2	P3	P4	P5	P6	P7
Factors Correlation	0.92	0.88	0.83	0.76	0.76	0.78	0.74
	P8	**P9**	**P10**	**P11**	**P12**	**P13**	**P14**
Factors Correlation	0.85	0.93	0.94	0.73	0.78	0.75	0.89

Source : analysis result, 2012

Reliability test is a test to determine the reliability of the data can be trusted in order to detect any manipulation of the observer. In this study, the reliability of test used is the spearman born. Data is said to be reliable if R obtained R is greater than 80%. Because of the R value above 80%, then it can be stated that the data reliably in accordance with the historical because it shows the confidence level of 97.7%. So that could be done further analysis.

Multinomial logistic regression analysis is used to determine the effect of predictor variables on the response variable. Multinomial regression is used because there are three kinds of response variables, but the response variable does not have different level.

Hypothesis :

H0 : $\beta x_1 = 0$, drainage disturbance variables has no effect on the incidence of disaster due to sea level rise

H1 : $\beta x_1 \neq 0$, drainage disruption variable effects on the incidence of due to disaster sea level rise.

significance level:: $\alpha = 0.05$

Critical areas: Reject H0 if the values

W2 (Wald) > $\chi^2_{(df,\alpha)}$ or P-value < α

From the above table it can be seen that the P-value valued at 0.018. The value P-value <0.05 alpha then reject H0, so that it can be concluded that the effect of drainage disruption due to the disaster due to sea level rise.

3.3. Identification of a disaster due to sea level rise

Flood hazard zones due to sea level rise illustrates the level of flood hazard zone in accordiance with the level of hazard from highest to lowest. Flood hazard zones derived from the overlay pool of variable height and duration of inundation. The method of analysis used in determining the level of flood hazard due to sea level rise that is by using Weighted Overlay. Each variable will be made in accordance with the hazard map data already existed and are regrouped into 5 classes. From both of these variables will be found each map and then overlay with weights on each map is 1.

3.4. Determining of influential factors of vulnerability

In analyzing the factors that influence vulnerability to floods due to sea level rise on coastal areas Surabaya analyzer using Delphi as a fixation of the factors that affect vulnerabilityand then weight factor will be determined using the AHP. where the weights are used to pmbuatan vulnerability zone maps. With the acquisition of the weighting in each of the determinants of vulnerability assessment of flooding due to sea level rise, the next stage wighted overlay analysis using ArcGIS 9.3 sum to determine the zoning on the level of vulnerability of coastal areas Surabaya. Here is a map-making stage Vulnerability Zone. Making a map based on sub factors affecting vulnerability of flooding due to sea level rise. wherein each of these maps will be classified into five classifications based on the Guidelines on Control of Flood Prone Areas is

- Not vulnerable
- Slightly Vulnerable
- Quite Vulnerable
- Vulnerable
- Highly Vulnerable

for such classification, the data will be compared between each existing Sub factor with the applicable standards or Surabaya in Indonesia. For example, for Sub topographic factors:

Table 4. Clasification Class of Topograpgy Based on Vulnerability Level

Factors	Scale	Classification		Explanation
Topography of the land	>15m	Not vulnerable	1	Description of scale using the standard issue by the department of marine and fisheries, 2004
	10m-15m	Less vulnerable	2	
	5m-10m	Quite vulnerable	3	
	2m-5m	Vulnerable	4	
	0m-2m	Highly vulnerable	5	

Based on existing data, Surabaya Coastal Zone is Located on the topography with a height of 0-6 meters. Therefore, when it is compared with the table it was found that the topography in Surabaya Coastal Zone is divided into three classes, namely:

- 0-2 meters (5 Classification or highly vulnerable)
- 2.1 to 5 meters (classification 4 or Vulnerable)
- 5.1 to 10 Meters (3 or fairly susceptible of classification)

From the division it will be created maps using ArcGIS 9.3. From this stage we will get a map of each sub factor. The following are the results topographic factor maps

- Having obtained a map of each sub-factor, then create a map Based on factors that influence susceptibility flooding due to Sea level rise using the overlay ArcGIS 9.3 and the weights of the AHP. Where there are 4 flood vulnerability factor (Guide Introduction Characteristics of Disasters in Indonesia and mitigation, 2005) that environmental factors, physical factors, social factors and economic factors. For example, to physical factors.
- Having found each of the four maps, all four maps will be in use arc gis overlay with weights that have been obtained from the analysis of AHP to obtain Flood Vulnerability Due to Sea Level Rise map. The following is a formulation of the vulnerability map.

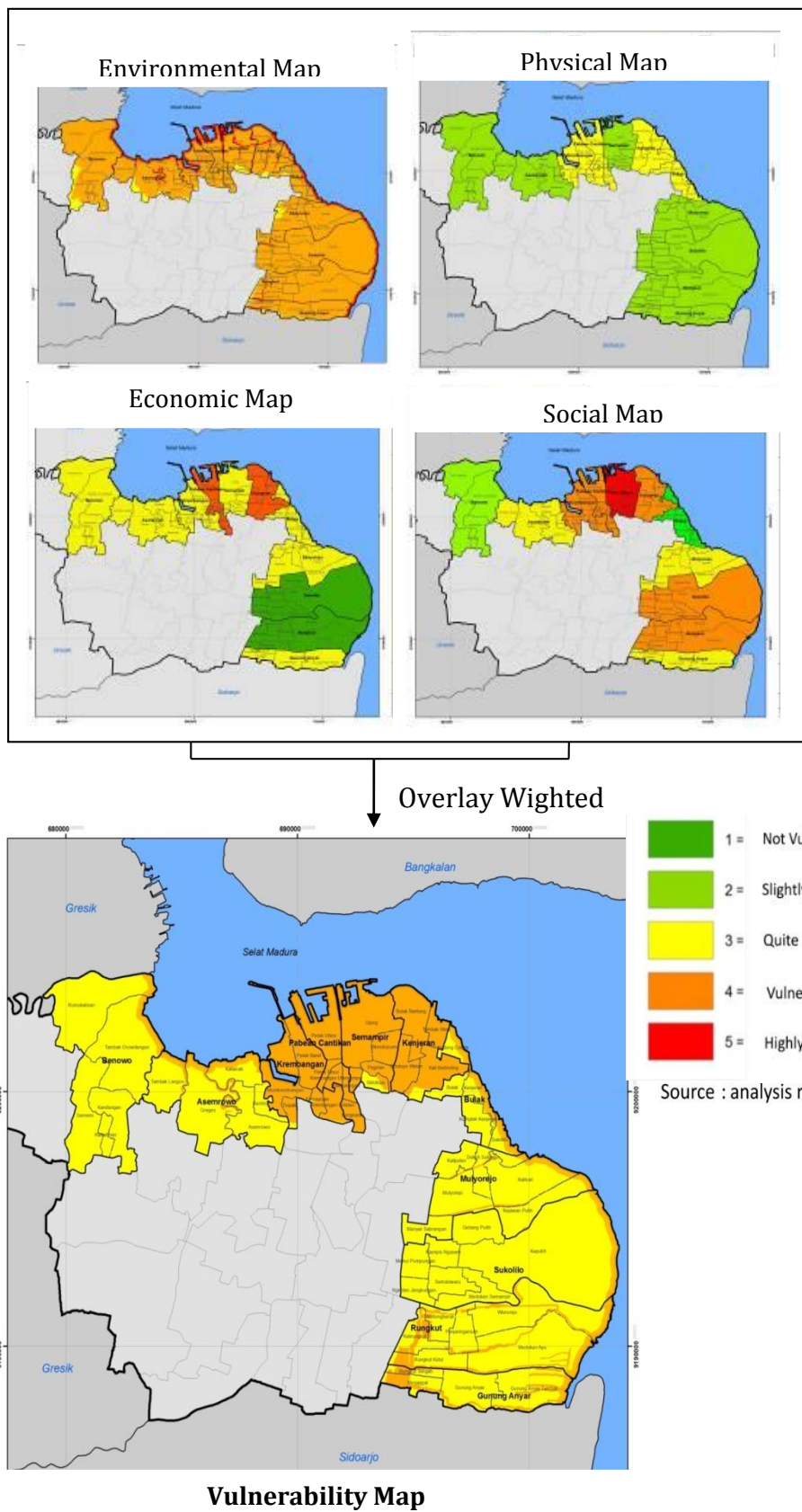
Conclusion

Spatial distribution of the hazard rate (hazard) of floods due to sea level rise on coastal areas Surabaya is a whole sub-districts which are along the coast. Districts that have the highest level of flood hazard area due to sea level rise sre Mulyorejo District, Kenjeran District ,Bulak District.

Spatial distribution of zones level of floods vulnerability due to sea level rise on coastal areas along the coast of Surabaya, the areas at the highest level of vulnerability are the District Krembangan, Pabenancantikan, Semampir and Kenjeran.

Spatial distribution of zones of of floods risk level due to sea level rise on coastal areas along the coast of Surabaya in Surabaya, the areas at highest risk are Krembangan District, District and Sub Asemrowo Bulak.

Influential factor in the formulation of of floods risk zones due to sea level rise in coastal areas Surabaya is the height of the flood, flood duration, Replace sea water, rainfall, distance to the river Proximity, Proximity distance to the coastline, the height of topography, soil type, Tata order land, density of buildings, road networks, population density, population growth rate, elderly + toddler (aged vulnerable), household sector working farms and the number of poor households.

Vulnerability Map

11 Kajian Kenaikan Muka Air Laut dan Strategi Adaptasinya di Kawasan Pesisir Kabupaten Tuban

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Abstrak – *Kabupaten Tuban, salah satu kabupaten yang berada di Jawa timur, yang langsung berbatasan dengan Laut Jawa dengan garis pantai sepanjang 65 km menjadikan kawasan pesisirnya rentan terhadap dampak kenaikan muka air. Prediksi kenaikan muka air dilakukan dengan mengadopsi data pasang surut daerah Semarang yang kemudian ditambah dengan faktor koreksi. Tren kenaikan muka air lautnya mengikuti persaman garis y = 0,0006x +0.96666. Dampak yang terjadi dengan naiknya muka air laut adalah tergenangnya daratan seluas 0,3% dari luas wilayah daratannya dengan kerugian total sebesar Rp.7.237.907.092,95. Untuk mengantisipasi dampak kenaikan muka air laut ini, perlu dilakukan sebuah tindakan adaptasi yang terdiri dari pola protektif, pola akomodasi dan pola retreat.*

Kata Kunci **:** *Tuban, kenaikan muka air laut, kerugian , dampak, least square.*

I. PENDAHULUAN

SEA LEVEL RISE adalah fenomena naiknya muka air laut sebagai akibat dari perubahan iklim yang merupakan isu penting saat ini. Terlebih lagi bagi Indonesia, negara Kepulauan yang memiliki + 18.110 pulau serta garis pantai sepanjang 108.000 km, terpanjang kedua setelah Kanada.

Laporan dari Intergovernmental Panel on Climate change (IPCC) memperkirakan bahwa pada kurun waktu 100 tahun terhitung mulai tahun 2000 permukaan air laut akan meningkat setinggi 15-90 cm dengan kepastian peningkatan setinggi 48 cm.[1] Kemudian dalam rujukan [2] juga melakukan proyeksi kenaikan muka air laut untuk wilayah Indonesia, yang menunjukkan wilayah Indonesia mengalami kehilangan daratan-daratan akibat kenaikan muka air laut. Jika diambil hasil proyeksi untuk tahun 2010, 2050 dan 2100 dengan daratan yang hilang secara berturut-turut seluas 7408 km2, 30120 km2, 90260 km2.

Wilayah pesisir yang merupakan batas antara darat dan laut menjadikannya sebagai daerah yang cukup berpotensi, terbukti sebagian besar masyarakat Indonesia tersebar didalamnya. Secara sosial, wilayah pesisir dihuni tidak kurang dari 110 juta jiwa atau 60% dari penduduk Indonesia yang bertempat tinggal dalam radius 50 km dari garis pantai. Dan 65% penduduk Pulau Jawa hidup di pesisir pantai dengan tingkat pertumbuhan Penduduk Pesisir Jawa mencapai angka 2,2% pertahun (di atas pertumbuhan penduduk rata-rata nasional.

Perubahan temperatur atmosfer menyebabkan kondisi fisik atmosfir kian tak stabil dan menimbulkan terjadinya anomali-anomali terhadap parameter cuaca yang berlangsung lama. Dalam ja ngka panjang anomali-anomali parameter cuaca tersebut akan menyebabkan terjadinya perubahan iklim. Peningkatan suhu air laut dan melelehnya volume es di daerah kutub meningkatkan volume laut. Kontribusi relatif dari meningkatnya suhu dan pencairan es terhadap kenaikan muka air laut adalah tidak pasti dan perkiraan ini dapat sangat bervariasi. Kedua faktor tersebut dapat meningkatkan tinggi muka air laut. [3]

Rujukan [4] menuliskan bahwa pesisir yang rentan terhadap kenaikan muka air laut, salah satunya adalah kawasan pesisir yang terletak di Pantai Utara Jawa. Fokus daerah pada penelitian ini adalah kawasan pesisir Kabupaten Tuban yang terdiri dari 5 Kecamatan, yaitu : Kecamatan Bancar, Kecamtan Jenu, kecamatan Tambakboyo, kecamatan Palang, dan

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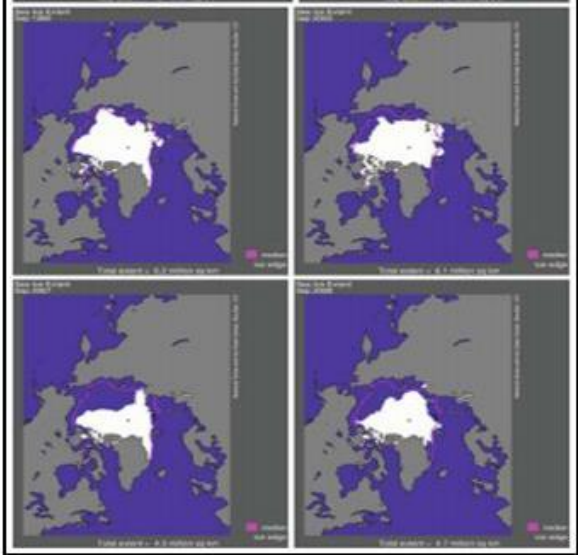
Kecamatan Tuban. Pemilihan kawasan pesisir Tuban didasarkan pada letaknya yang berbatasan langsung dengan Laut Jawa serta berada di jalur transportasi darat Pantura selain itu didasarkan pada kecendrungan pertumbuhan pesisir Tuban yang memiliki potensi sebagai kawasan utama penggerak ekonomi wilayah gelangban.

Gambar. 1. Berkurangnya luas es di daerah kutub dari tahun 1993, 2003, 2007 dan 2008

Seperti kata pepatah, lebih baik mencegah daripada mengobati, maka ada baiknya pula dilakukan evaluasi dini terkait dampak kenaikan muka air laut terhadap kawasan pesisir yang nantinya sebagai acuan dalam strategi adaptasinya. Terjadinya perubahan lingkungan yang secara teoritis diakibatkan oleh naiknya permukaan air laut, akan menimbulkan pengaruh yang besar terhadap masyarakat pesisir. Dalam hal ini, bagaimana masyarakat, khususnya masyarakat pesisir menyikapi perubahan lingkungan yang ada sebagai dampak dari kenaikan muka air menjadi isu lain yang patut diperhatikan secara tepat.

II. URAIAN PENELITIAN

A. Pengolahan Pasang Surut

Dalam memprediksi kenaikan muka air laut, dapat menggunakan data pasang surut. Oleh karena keterbatasan data, maka dalam memprediksi kenaikan muka air lautnya mengadopsi data pasang surut daerah semarang dari tahun 1985 – Februari 2012. Sebelum diadopsi maka terlebih dahulu dicari faktor koreksinya, yaitu selisih tinggi antara msl tuban dan semarang di waktu yang sama. Setelah itu, msl tuban hasil adposi adalah msl semarang yang ditambah dengan faktor koreksi. Dalam pengolahan pasang surut menggunakan metode least square. Adapun persamaan metode least square adalah sebagai berikut:

$$\{F\} = \{H\} \quad \{X\} \qquad (1)$$

$$\begin{bmatrix} \sum_{t=1}^{m} \eta(t)Cos(w_1 t) \\ \vdots \\ \sum_{t=1}^{m} \eta(t)Cos(w_{k+1} t) \\ \sum_{t=1}^{m} \eta(t)Cos(w_1 t) \\ \vdots \\ \sum_{t=1}^{m} \eta(t)Cos(w_k t) \end{bmatrix} =$$

$$\begin{bmatrix} CC_{1,1} & \dots & CC_{K+1,1} & SC_{1,1} & \dots & SC_{k,1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ CC_{1,k+1} & \dots & CC_{k+1,k+1} & SC_{1,k+1} & \dots & SC_{k,k+1} \\ CS_{1,1} & \dots & CS_{k+1,1} & SS_{1,1} & \dots & SS_{k,1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ CS_{1,k} & \dots & CS_{k+1,k} & SS_{1,k} & \dots & SS_{k,k} \end{bmatrix} x \begin{bmatrix} A_1 \\ \vdots \\ A_{k+1} \\ B_1 \\ \vdots \\ B_k \end{bmatrix}$$

B. Peta Wilayah Genangan

Peta wilayah genangan adalah visualisasai daerah-daerah genangan. Adapun data yang dibutuhkan adalah topografi digital DEM SRTM serta input kenaikan muka air laut. Asumsi yang digunakan dalam membuat peta wilayah genangan adalah daerah yang tergenang merupakan daerah dengan topografi yang lebih rendah dari kenaikan muka air laut dan air dapat mengalir melalui celah-celah kecil topografi layaknya sifat air yang selalu mengalir dari tempat yang tinggi ketempat yang rendah.

C. Dampak dan Kerugian Ekonomi

Dampak yang muncul akibat kenaikan muka air laut dapat dilihat dari peta visualisasi genangan yang dibuat dengan mengoverlaykan dengan peta tata guna lahan existing. Dalam menghitung kerugian ekonominya didasarkan pada jenis lahan yang tergenanga, yang terbagi menjadi 3 jenis, yaitu :

1) Lahan Basah

   Merupakan lahan yang penuh dengan keanekaragaman hayati dan merupakan wilayah konservasi. Yang termasuk kedalam jenis ini adalah rawa. Besarnya nilai lahan basah perhektarnya dapat dihitung menggunakan persamaan toll.[5]

$$\gamma = \frac{\left(GDP/_{Capita}\right)}{1+\left(GDP/_{Capita}\right)} \qquad (2)$$

2) Lahan Kering

   Lahan yang digunakan untuk kegiatan ekonomi dimana kerugiannya menjadi

tanggung jawab pemilik. Nilai lahan kering dihitung dari output ekonomi persegmen area.

$$\delta = (economic\ output\ multiplier) * GDP \quad (3)$$

3) Lahan Pemukiman
Wilayah permukiman merupakan wilayah yang mempunyai perhitungan tersendiri. Kerugian ekonomi pada wilayah pemukiman diduga dengan menghitung luas wilayah terendam dan nilai lahan terbangun dari wilayah tersebut. [6]

D. Strategi Adaptasi

Dalam merencanakan srategi adaptasi perlu memperhatikan karakteristik wilayahnya, permasalah lokal yang ada serta dampak akibat kenaikan muka air laut itu sendiri. Sehingga semua masalah yang ada dapat terpecahkan dengan baik dan tidak saling tumpang tindih.

III. HASIL DAN PEMBAHASAN

A. Gambaran Umum Wilayah

Kabupaten Tuban merupakan salah satu kabupaten yang terletak di Jawa Timur. Secara astronomis, Kabupaten Tuban berada di 111030' – 112035' BT dan 6040' – 7018' LS dimana luas wilayah daratan adalah 1839,94 km2 dan lautan seluas 22.608 km2 dengan panjang wilayah pantai 65 Km. Adapun batas-batas wilayah Kabupaten Tuban adalah sebagai berikut:

Utara	: Laut Jawa
Timur	: Kabupaten Lamongan
Selatan	: Kabupaten Bojonegoro
Barat	: Rembang dan Blora

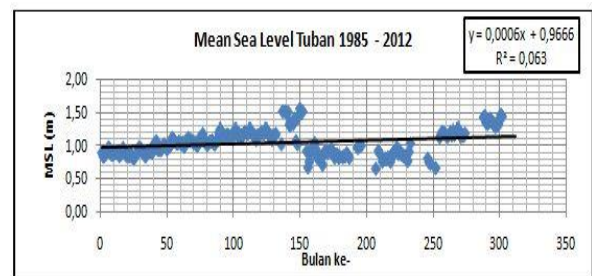
Kabupaten tuban terdiri dari 20 kecamatan namun yang menjadi fokus studi adalah 5 kecamatan yang terletak di sepanjang garis pantainya yaitu Kecamatan Bancar, Kecamatan Tambakboyo, Kecamatan Jenu, Kecamatan Tuban dan Kecamatan Palang.

Gambar 2. Peta daerah studi, Kawasan pesisir Kabupaten Tuban

Jumlah penduduk Kabupaten Tuban pada tahun 2010 adalah 1.259.996. Dengan komposisi laki-laki 630.881 dan perempuan berjumlah 629.115. Kepadatan penduduk tahun 2010 adalah 685 jiwa/km2. Kecamatan yang paling padat adalah kecamatan Tuban dengan kepadatan 2.025 jiwa/ km2.

Angka Pendapatan Domestik Regional Bruto (PDRB) Kabupaten Tuban atas dasar harga berlaku pada tahun 2010 sebesar Rp.19.040,92 milyar. Sedangkan untuk angka PDRB atas dasar harga konstan sebesar Rp 8.468,92 milyar. Pertumbuhan ekonomi kabupaten Tuban mencapai 6,22 persen dengan laju inflasi pada tahun 2010 adalah 5,58%. Pendapatan regional perkapita Kabupaten Tuban tahun 2010 berdasarkan harga berlaku adalah sebesar Rp.14.565.728, sedangkan pendapatan perkapita berdasarkan harga konstan tahun 2000 adalah sebesar Rp.6487.088. Pendapatan perkapita adalah produk regional neto atas biaya faktor produksi dibagi jumlah penduduk pertengahan tahun.[7]

B. Prediksi Kenaikan Muka Air Laut

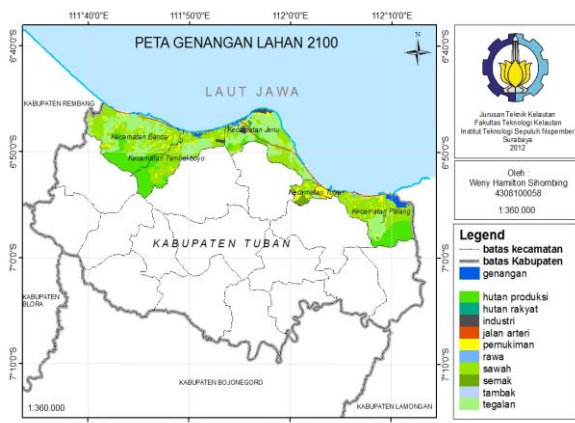
Tren kenaikan muka air laut di Kabupaten tuban mengikuti persamaan garis . Dengan laju kenaikan muka air laut sebesar 7,2 mm / tahunnya.

Gambar.3. Peta daerah studi, Kawasan pesisir Kabupaten Tuban

Sehingga dengan persamaan tersebut dapat diprediksi muka air laut untuk beberapa tahun kedepan, seperti yang terlihat pada grafik berikut :

Gambar. 4. Peta daerah studi, Kawasan pesisir Kabupaten Tuban.

C. Dampak dan Kerugian Ekonomi

Ditahun 2100, diprediksikan akan mencapai 1,8 m, hal ini memiliki dampak sebagai berikut :

1. Berkurangnya daratan seluas 417,9 ha atau 0,3% dari luas wilayah daratannya
2. Terganggunya Kegiatan sosial ekonomi masyarakat setempat
3. Terjadinya perubahan garis pantai
4. Terganggunya jalur transportasi

Gambar. 5. Peta Genangan Lahan 2100

Jika digolongkan menurut jenis lahan yang tergenang maka lahan yang paling banyak digenangi adalah lahan tambak sebesar 78% dan yang paling sedikit adalah lahan industri sebesar 2% dengan total kerugian ekonomi sebesar Rp.7.237.907.092,95. Dimana harga rumah diasumsikan 20.000.000 rupiah sedangkan harga lahan basah perhektarnya adalah 32.000.904,416. Dan untuk lahan basah, menurut rujukan [8] adapun angka pengganda output untuk industri adalah 1,516 dan untuk sawah sebesar 2,197.

D. Strategi Adaptasi

Alam adalah sebuah sistem yang dinamis dan tetap stabil Alam adalah sebuah sistem yang dinamis dan tetap stabil (seimbang), ketika tidak ada gaya dari luar yang mengganggu. Sebagai seorang sahabat, sejatinya manusia juga adalah seorang musuh bagi alam. Banyak sekali kegiatan manusia dimuka bumi ini yang menggangu kestabilan sistem alam sehingga terjadi beberapa perubahan. Kenaikan muka air laut adalah salah satu indikasinya.

Layaknya jerapah berleher panjang yang lolos dari seleksi alam dikarenakan mampu beradaptasi, demikianlah hendaknya manusia. Adaptasi merupakan salah satu respon yang tanggap perubahan, yaitu dengan cara menyesuaikan diri terhadap perubahan yang terjadi. Dalam merencanakan strategi adaptasi, tentunya harus mempertimbangkan karakteristik wilayahnya, permasalahan lokal yang ada serta dampak yang akan terjadi akibat ancaman kenaikan muka air laut.

Dalam rujukan [9] menuliskan ada 3 pola adaptasi, (i) pola protektif (ii) pola akomodasi (iii) pola retreat. Ketiga pola tersebut dapat menjadi acuan yang tepat.

Tabel 1.
Kerugian Ekonomi berdasarkan Jenis Lahan yang Tergenang

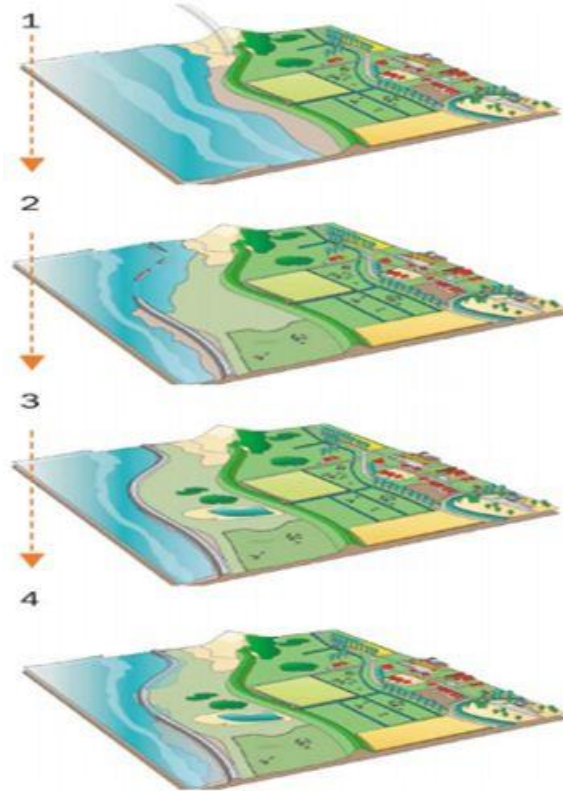
Jenis Lahan	Luas Lahan	Kerugian (Rp.)
Industri	7,81	Rp.172.356.061,33
Pemukiman	11,49	Rp.229.846.000,00
Sawah	56,08	Rp.1.794.946.729,15
Tambak	318,49	Rp.4.639.073.349,97
Tegalan	12,55	Rp.401.684.952,50
Total	417,41	Rp.7.237.907.092,95

Gambar. 6. Peta daerah studi, Kawasan pesisir Kabupaten Tuban

Pola protektif, adalah cara beradaptasi dengan membangun struktur pelindung pantai, seperti seawall, breakwater. Pola ini cukup tepat diaplikasikan di semua kecamatan, khususnya tambakboyo yang didominasi oleh pemukiman nelayan, karena didominasi oleh pemukiman nelayan. Pola Akomodasi merupakan adaptasi dengan cara mulai beralih pada tambak pasang-surut, diversifikasi varietas tambak, meninggikan bangunan dan jalan serta melakukan pengurugan.

Gambar. 7 Salah satu bentuk adaptasi proteksi

Mengingat banyaknya pemukiman dan jalan yang berbatasan langsung dengan jalan, pengurugan adalah salah satu cara yang tepat, atau juga dapat

disebut sebagai Front shore deffence, dimana mereklamasi daratan dengan tipologi menyambung dengan daratan induk, dan daratan yang baru dijadikan sebagai pelindung. Tipe ini bisa diaplikasikan di Kecamatan Tuban dan Jenu serta Palang Dan yang terakhir pola retreat, beradaptasi dengan cara meninggalkan tempat yang lama dan beralih kedaerah yang lebih aman.

Gambar. 7. Self defence

IV. KESIMPULAN

Kajian mengenai dampak kenaikan muka air Laut sangat penting untuk dilakukan, hal ini merupakan salah satu sikap yang tanggap dalam mengatasi masalah sehingga nantinya bisa dirumuskan dengan tepat strategi adaptasinya. Diharapkan Studi ini bisa dilanjutkan dengan melakukan zonasi terhadap wilayah pesisirnya, atau melakukan studi yang sama dengan formula genangan yang lebih tepat

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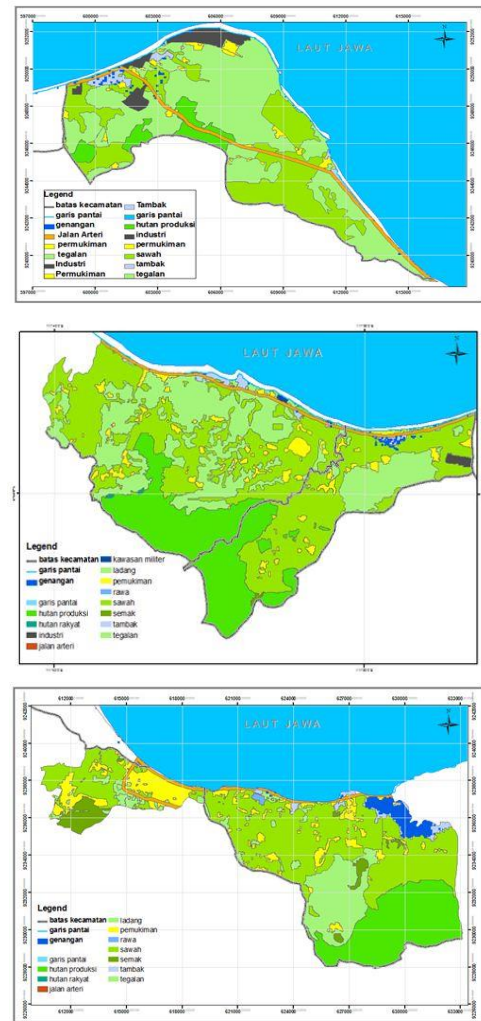
LAMPIRAN

Gambar. 8. Peta wilayah genangan Kecamatan Bancar-Tambakboyo (atas), Kecamatan Jenu (tengah) dan kecamatan Tuban-Palang (bawah)

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Analisa Perubahan Garis Pantai Akibat Kenaikan Muka Air Laut di Kawasan Pesisir Kabupaten Tuban

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Abstrak – *Pemanasan global dan perubahan iklim memberikan dampak yang signifikan terhadap kegiatan manusia maupun lingkungan secara alami. Ancaman utama dari perubahan iklim ini adalah kenaikan muka air laut (sea level rise) yang bisa menyebabkan banjir di daerah pesisir, erosi pada pantai berpasir dan terjadinya kerusakan infrastruktur yang berada di dekat pesisir. Kabupaten Tuban sebagai bagian dari Pantai Utara (Pantura) yang memiliki panjang garis pantai 65 km berpotensi mengalami dampak dari fenomena naiknya muka air laut ini, sehingga perlu dilakukan penelitian. Perhitungan kenaikan muka air laut berdasarkan data pasang surut selama 27 tahun dengan menggunakan metode Least Square untuk mengetahui nilai muka air rerata (Mean Sea Level). Kemudian dilakukan regresi linier terhadap nilai MSL sehingga didapatkan persamaan besarnya peningkatan muka air laut. Sedangkan perhitungan perubahan garis pantai menggunakan metode Bruun Rule yang memiliki persamaan R = S(L/(B+h)). Hasil perhitungan menunjukkan kenaikan muka air laut di Kabupaten Tuban adalah sebesar 7.2 mm per tahun dan kemunduran garis pantai 0.7 meter setiap tahunnya.*

Kata Kunci **:** *Bruun Rule, MSL, Pantai, Sea Level Rise, Tuban.*

I. PENDAHULUAN

KENAIKAN muka air laut merupakan fenomena naiknya muka air laut akibat pertambahan volume air laut. Perubahan tinggi permukaan air laut dapat dilihat sebagai suatu fenomena alam yang terjadi secara periodik maupun menerus. Perubahan secara periodik dapat dilihat dari fenomena pasang surut air laut, sedangkan kenaikan air laut yang menerus adalah seperti yang teridentifikasi oleh pemanasan global. Fenomena naiknya muka air laut yang direpresentasikan dengan SLR (sea level rise) dipengaruhi secara dominan oleh pemuaian thermal (thermal expansion) sehingga volume air laut bertambah. Selain itu, mencairnya es di kutub dan gletser juga memberikan kontribusi terhadap perubahan kenaikan muka air laut.

Kenaikan muka air laut bisa menyebabkan berkurangnya atau mundurnya garis pantai, mempercepat terjadinya erosi pantai berpasir, banjir di wilayah pesisir, dan kerusakan infrastruktur yang berada di wilayah pesisir seperti dermaga, dan bangunan pantai lainnya. Hal ini semakin lama akan semakin mengganggu masyarakat yang tinggal di wilyah pesisir. Kabupaten Tuban sebagai bagian dari wilayah Pantai Utara (Pantura) memiliki panjang garis pantai 65 km, dimana wilayah pantai terbentang di lima (5) kecamatan. Banyak penduduk yang tinggal di wilayah pesisir. Oleh karena itu, perlu dilakukan penelitian tentang perubahan garis pantai yang terjadi dan prediksi perubahan garis pantai untuk tahun-tahun mendatang sehingga bisa disusun langkah atau strategi untuk menanggulangi dampak dari fenomena kenaikan muka air laut ini.

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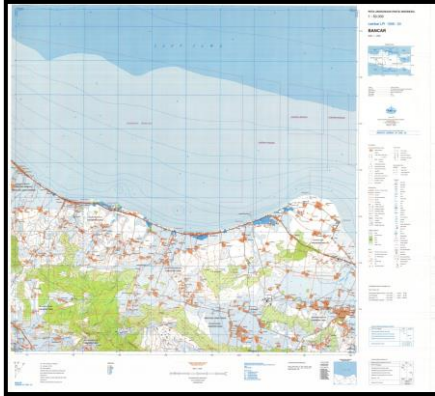
II. URAIAN PENELITIAN

A. Pengumpulan Data

Lokasi penelitian ini dibatasi hanya mencakup pantai di Kecamatan Tambakboyo, Kabupaten Tuban. Data-data sekunder yakni data pasang surut, peta batimetri dan garis pantai didapatkan dari dinas terkait. Oleh karena keterbatasan data, data pasang surut mengadopsi dari data pasang surut Semarang

selama 27 tahun yang telah ditambahkan faktor koreksi. Sedangkan Peta Batimetri ada dua (2), yaitu peta batimetri LPI tahun 2005 dengan survei hidrografi tahun 2001, 2002 dan peta batimetri Alur Pelayaran tahun 2001 (yang dikeluarkan oleh Dinas-Hidrooseanografi) dengan survei hidrografi tahun 1994-1999. Juga peta RBI tahun 1999 yang menunjukkan garis pantai sebagai acuan awal perhitungan perubahan garis pantai.

Gambar. 1. Peta LPI Tuban tahun 2005 (Sumber: BAKOSURTANAL)

B. Analisa Kenaikan Muka Air Laut

Analisa kenaikan muka air laut dari data pasang surut menggunakan metode least square yang diolah per bulan dimana dalam perhitungannya dibantu dengan software fortran. Least Square adalah metode pengolahan data pasang surut dengan menggunakan pendekatan fungsi sinus cosinus yang menghasilkan output berupa elevasi muka air laut, komponen bilangan formzal dan jenis pasang surut. Adapun rumus perhitungan metode least square adalah sebagai berikut [1]:

$$\underbrace{\{F\}}_{(2k+1)\times 1} = \underbrace{[H]}_{(2k+1)\times(2k+1)} \underbrace{\{X\}}_{(2k+1)\times 1} \quad (1)$$

$$\begin{bmatrix} \sum_{t=1}^{m} \eta(t)Cos(\omega_1 t) \\ \vdots \\ \sum_{t=1}^{m} \eta(t)Cos(\omega_{k+1} t) \\ \sum_{t=1}^{m} \eta(t)Sin(\omega_1 t) \\ \vdots \\ \sum_{t=1}^{m} \eta(t)Sin(\omega_k t) \end{bmatrix} = \begin{bmatrix} cc_{1,1} & \cdots & cc_{k+1,1} & sc_{1,1} & \cdots & sc_{k,1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ cc_{1,k+1} & \cdots & cc_{k+1,k+1} & sc_{1,k+1} & \cdots & sc_{k,k+1} \\ cs_{1,1} & \cdots & cs_{k+1,1} & ss_{1,1} & \cdots & ss_{k,1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ cs_{1,k} & \cdots & cs_{k+1,k} & ss_{1,k} & \cdots & ss_{k,k} \end{bmatrix} \times \begin{bmatrix} A_1 \\ \vdots \\ A_{k+1} \\ B_1 \\ \vdots \\ B_k \end{bmatrix} \quad (2)$$

Setelah diketahui nilai MSL tiap bulan, selanjutnya nilai MSL diplotkan dalam grafik kemudian dilakukan regresi linear sehingga mendapatkan persamaan:

$$Y = ax + b \quad (3)$$

Dimana,

Y = nilai MSL (m)

x = fungsi waktu (bulan)

C. Analisa Perubahan Garis Pantai

Secara sederhana proses perubahan garis pantai disebabkan oleh angin dan air yang bergerak dari suatu tempat ke tempat lain, mengikis tanah dan kemudian mengendapkannya di suatu tempat secara kontinu [3]. Analisa perubahan garis pantai pada penelitian ini menggunakan metode Bruun [4] yang memiliki rumus sebagai berikut:

$$R = S(L/(B+h)) \quad (4)$$

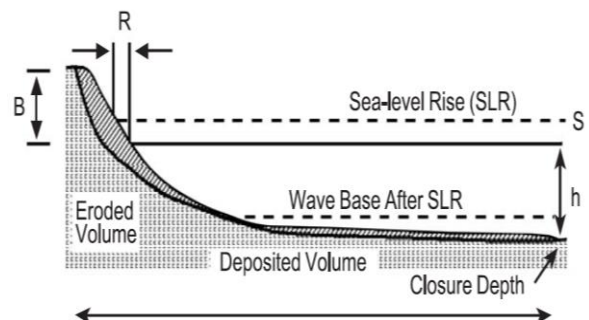
Dimana,

R = laju perubahan garis pantai

S = kenaikan muka air laut

L = panjang profil pantai

B = ketinggian pantai

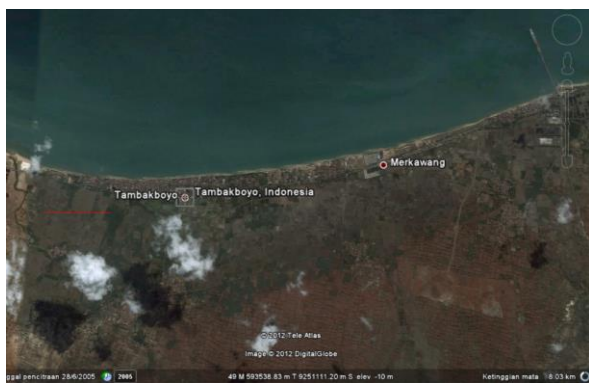
h = kedalaman pantai pada *closure depth*

Gambar. 2. Sketsa Erosi Garis Pantai Bruun Rule

D. Validasi

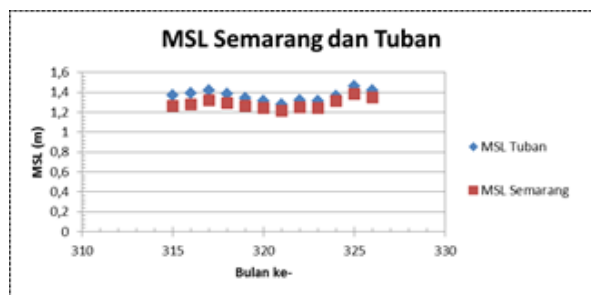
Validasi dilakukan untuk mengetahui keakuratan pemodelan. Dalam penelitian ini, pemodelan perubahan garis pantai menggunakan metode Bruun divalidasi dengan Google Earth tahun 2005. Validasi dilakukan untuk R (kemunduran garis pantai) tiap pias, dimana ada 200 pias dengan jarak tiap pias adalah 35.82 m.

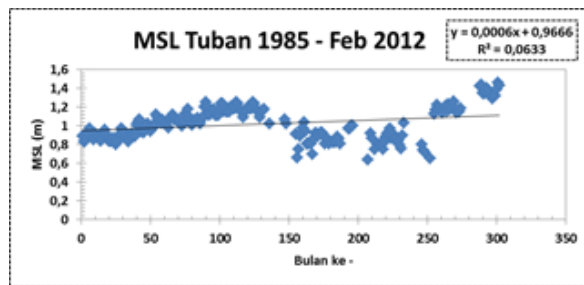
III. HASIL DAN DISKUSI

A. Lokasi Penelitian

Lokasi penelitian ini adalah di pantai sepanjang Kecamatan Tambakboyo Tuban yang secara geografis terletak pada 111°,49' – 111°,53' BT dan 6°,47.5' – 6°,48.1' LS. Kondisi pantai berpasir dengan panjang 7 km dan kemiringan sekitar 0.01

Gambar. 3. Lokasi Penelitian, Kecamatan Tambakboyo (sumber: *google Earth)*

B. Analisa Kenaikan Muka Air Laut

Dari hasil perhitungan dengan menggunakan metode Least Square didapatkan nilai MSL untuk Tuban dan Semarang tiap bulan. Dari data pasang surut yang tersedia yaitu Maret 2011 – Februari 2012 didapatkan faktor koreksi MSL antara Tuban dan Semarang adalah sebesar 0.08 m.

Gambar. 4. Grafik MSL Semarang dan Tuban

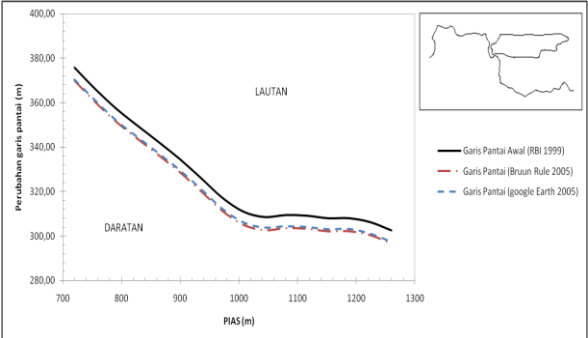
Berikut MSL untuk Tuban yang diperoleh dari adopsi data Semarang setelah ditambah faktor koreksi sebesar 0.08:

Gambar. 5. Grafik Kenaikan Muka Air Laut

Dari grafik di atas didapatkan persamaan kenaikan muka air laut untuk Tuban y = 0.0006x + 0.9666 untuk x = fungsi waktu (bulan) dan y = MSL (m). Sehingga dari persamaan tersebut dapat diprediksi kenaikan muka air laut untuk tahun-tahun mendatang sebagai berikut:

Tabel 1.
Nilai Kenaikan Muka Air Laut

Tahun	MSL (m)	S (m)	Keterangan
1999	1.0746	-	Data awal sebagai acuan/titik nol (0)
2005	1.1178	0.0432	Untuk Validasi
2050	1.4418	0.3672	Prediksi
2100	1.8018	0.7272	Prediksi

C. Analisa Perubahan Garis Pantai

Dalam analisa perubahan garis pantai, pantai dibagi menjadi 200 pias supaya mendapatkan hasil yang akurat. Komponen data pada perhitungan dengan metode Bruun adalah kenaikan muka air laut (S) yang diperoleh dari hasil analisa pasang surut, ketinggian pantai (B) dianggap sama yaitu dua (2) m, closure depth (h) yang diperoleh dari overlay dua (2) peta batimetri dengan tahun yang berbeda yaitu sebesar delapan (8) m, dan panjang profil pantai (L) yang berbeda-beda untuk tiap pias. Dengan memasukkan ke persamaan (11) untuk pias 1 dengan nilai L = 1530.89 m didapatkan kemunduran garis pantai (R) sebagai berikut:

$R = S(L/(B+h))$

$= 0.0072(1530.89/(2+8))$

$= 1.07$ m

Dengan cara yang sama seperti di atas, dilakukan perhitungan untuk seluruh pias (200 pias) dan didapatkan nilai R rata-rata adalah 0.7 m per tahun.

Tabel 2.
Hasil perhitungan garis pantai (R) 20 pias selama 1 tahun

GARIS PIAS	S(m)	h(m)	L(m)	B(m)	R(m)
1	0.0072	8	1530.89	2	1.07
2	0.0072	8	1531.58	2	1.07
3	0.0072	8	1531.93	2	1.07
4	0.0072	8	1531.54	2	1.07
5	0.0072	8	1530.93	2	1.07
6	0.0072	8	1530.52	2	1.07
7	0.0072	8	1529.28	2	1.07
8	0.0072	8	1527.27	2	1.07
9	0.0072	8	1525.91	2	1.07
10	0.0072	8	1524.94	2	1.07
11	0.0072	8	1523.25	2	1.07
12	0.0072	8	1521.43	2	1.07
13	0.0072	8	1519.49	2	1.06
14	0.0072	8	1516.98	2	1.06
15	0.0072	8	1514.13	2	1.06
16	0.0072	8	1511.30	2	1.06
17	0.0072	8	1509.00	2	1.06
18	0.0072	8	1507.77	2	1.06
19	0.0072	8	1507.07	2	1.05
20	0.0072	8	1505.62	2	1.05

D. Validasi dan Prediksi

Validasi dilakukan antara R (kemunduran garis pantai) hasil perhitungan menggunakan metode Bruun dengan R yang ditunjukkan oleh Google Earth. Dari validasi ini akan terlihat keakuratan perhitungan perubahan garis pantai menggunakan metode Bruun sehingga bisa digunakan untuk memprediksi perubahan garis pantai tahun-tahun berikutnya. Dengan perhitungan yang sama seperti pada pembahasan C dengan nilai S yang berbeda didapatkan selisih R sebagai berikut:

Tabel 3.
Perbandingan nilai R 20 pias hasil validasi

Garis Pias	R metode Bruun (m)	R Google Earth (m)
1	6.12	5.12
2	6.13	5.11
3	6.13	5.18
4	6.13	5.07
5	6.12	5.04
6	6.12	4.95
7	6.12	5.03
8	6.11	5.21
9	6.10	4.98
10	6.10	5.23
11	6.09	5.10
12	6.09	4.94
13	6.08	4.90
14	6.07	4.88
15	6.06	5.04
16	6.05	5.07
17	6.04	4.95
18	6.03	5.23
19	6.03	5.00
20	6.02	5.20

Hasil perhitungan menunjukkan pada tahun 2005 pantai mengalami kemunduran rata-rata 4.38 m sejak tahun 1999. Sedangkan peta Google Earth yang telah dioverlaykan dengan peta RBI 1999 menunjukkan kemunduran garis pantai rata-rata 3.45 m.

Gambar. 6. Grafik perubahan garis pantai hasil validasi 8 pias

Hasil validasi menunjukkan bahwa perbedaan garis pantai hasil perhitungan dengan metode Bruun dan garis pantai yang ditunjukkan oleh Google Earth tidak memiliki perbedaan yang begitu signifikan, yakni dengan nilai error sebesar 0.82 sehingga hasil perhitungan dari metode Bruun ini cukup bisa digunakan untuk memprediksikan kemunduran garis pantai tahun-tahun berikutnya. Adapun hasil prediksi perubahan garis pantai adalah sebagai berikut:

Tabel 3.
Perbandingan nilai R 20 pias hasil validasi

Garis Pias	R tahun 2050 (m)	R tahun 2100 (m)
1	56.64	111.75
2	56.67	111.81
3	56.68	111.83
4	56.67	111.80
5	56.64	111.76
6	56.63	111.73
7	56.58	111.64
8	56.51	111.49
9	56.46	111.39
10	56.42	111.32
11	56.36	111.20
12	56.29	111.06
13	56.22	110.92
14	56.13	110.74
15	56.02	110.53
16	55.92	110.32
17	55.83	110.16
18	55.79	110.07
19	55.76	110.02
20	55.71	109.91

Hasil perhitungan menunjukkan pada tahun 2050 pantai mengalami kemunduran rata-rata 40.21 meter selama 51 tahun terhitung sejak tahun 1999 dan pada tahun 2100 pantai mengalami kemunduran rata-rata 79.63 meter selama 101 tahun terhitung sejak tahun 1999.

Gambar. 7. Grafik prediksi perubahan garis pantai

E. Strategi Penanggulangan Dampak Kenaikan Muka Air Laut

Untuk mengantisipasi dampak yang ditimbulkan akibat kemunduran garis pantai ini perlu adanya strategi. Adapun strategi yang diusulkan untuk menanggulangi dampak perubahan garis pantai dalam studi ini adalah sebagai berikut:

1. Penanaman mangrove atau hutan bakau.
2. Pembangunan dinding pantai atau *revetment* yang memenuhi syarat perencanaan bangunan.
3. Pengembangan wilayah pesisir berbasis pada UU no. 27 tahun 2007 tentang Pengelolaan Pesisir dan Pulau-Pulau Kecil.

IV. KESIMPULAN / RINGKASAN

Dari analisis yang telah dilakukan, maka dapat diperoleh beberapa kesimpulan sebagai berikut:

1. Kenaikan muka air laut di kawasan pesisir Kabupaten Tuban mengikuti persamaan y = 0.0006x + 0.9666 dengan laju kenaikan 7.2 mm per tahun.
2. Kemunduran garis pantai di kawasan pesisir Kabupaten Tuban adalah 0.7 m per tahun.
3. Prediksi kemunduran garis pantai tahun 2050 adalah 40.21 m dan tahun 2100 adalah 79.63 m terhitung sejak tahun 1999.
4. Strategi yang diusulkan untuk menanggulangi dampak perubahan garis pantai di masa mendatang adalah penanaman mangrove, pembangunan dinding pantai atau *revetment* yang memenuhi syarat perencanaan bangunan, dan pengembangan wilayah pesisir berbasis UU no.27 tahun 2007.

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13 Analisa Skenario Perubahan Iklim untuk Memprediksi Kenaikan Muka Air Laut di Pesisir Kabupaten Tuban, Jawa Timur

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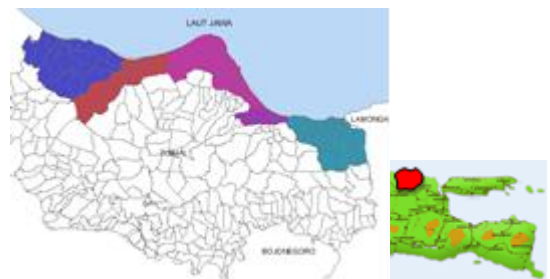
Abstrak – *Kenaikan muka air laut adalah salah satu dampak dari perubahan iklim dan pemanasan global yang terjadi akibat semakin meningkatnya aktivitas manusia yang akan menyebabkan terjadinya peningkatan konsentrasi gas rumah kaca di atmosfer. Dampak dari kenaikan muka air laut itu sendiri akan sangat dirasakan oleh daerah pesisir di negara-negara kepulauan, salah satunya adalah Indonesia (Kabupaten Tuban). Tujuan penulisan tugas akhir ini adalah untuk menganalisa skenario perubahan iklim apa yang sesuai dengan pesisir Kabupateb Tuban sehingga bisa digunakan untuk memprediksi kenaikan muka air laut yang terjadi selama beberapa tahun mendatang. Selain memprediksi kenaikan muka air laut, paramater lain yang akan diprediksi berkaitan dengan perubahan iklim yaitu perubahan temperatur serta presipitasi. Analisa skenario perubahan iklim pada penulisan tugas akhir ini menggunakan software MAGICC/SCENGEN, serta ER Mapper untuk pembuatan visualisasi daerah genangan. Dari hasil analisa diperoleh skenario perubahan iklim yang sesuai dengan pesisir Kabupaten Tuban adalah skenario B2AIM. Dan berdasarkan hasil analisa MAGICC diperoleh bahwa akan terjadi kenaikan sebesar 1.43 meter pada tahun 2050. Kemudian berdasarkan hasil analisa SCENGEN akan terjadi perubahan curah hujan yang cukup besar pada bulan Juli, Agustus, September dan Oktober. Dan akan terjadi kenaikan temperatur yaitu sebesar 1.56 °C pada tahun 2050.*

Kata Kunci **:** *kenaikan muka air laut, MAGICC/SCENGEN, perubahan iklim, skenario.*

I. PENDAHULUAN

Jumlah penduduk yang semakin meningkat serta semakin meningkat pula kegiatan industri, menyebabkan naiknya emisi Gas Rumah Kaca (GRK). Penghasil GRK yang terbesar adalah akibat aktivitas yang dilakukan oleh manusia. Dengan semakin meningkatnya GRK tersebut maka menyebabkan terjadinya pemanasan global dan perubahan iklim yang memberikan dampak yang cukup besar baik bagi manusia maupun bagi lingkungan

Ancaman terbesar dari pemanasan global dan perubahan iklim adalah kenaikan muka air laut yang bisa mengancam kehidupan manusia maupun ekosistem lain yang ada di kawasan pesisir. Dampak dari pemanasan global dan perubahan iklim berupa kenaikan muka air laut akan sangat dirasakan oleh banyak negara-negara kepulauan misalnya seperti Indonesia. Indonesia yang memiliki garis pantai sepanjang ± 81.000 km tentu saja akan sangat merasakan dampak yang terjadi akibat kenaikan muka air laut tersebut.

Gambar 1. Lokasi Kabupaten Tuban (diarsir warna merah)

Selain menyebabkan kenaikan muka air laut pemanasan global dan perubahan iklim juga menyebabkan terjadinya perubahan iklim global yaitu seperti berubahnya pola angin, pola presipitasi dan siklus hidrologi serta perubahan suhu udara dan air. Dengan memperhatikan dampak-dampak yang terjadi akibat pemanasan global dan perubahan iklim tersebut maka perlu dilakukan penelitian untuk mengetahui bagaimana perubahan iklim dan kenaikan muka air laut yang terjadi di Indonesia khususnya di daerah pesisir. Salah satu daerah studi yang bisa dilakukan

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sebagai lokasi studi penelitian tersebut adalah pantai utara jawa tepatnya pesisir Kabupaten Tuban, Jawa Timur.

II. URAIAN PENELITIAN

A. Studi Literatur

Pemanasan global telah mengakibatkan perubahan iklim di Indonesia [1]. Kondisi ini ditandai dengan meningkatnya frekuensi hujan dengan intensitas sangat tinggi, ketidakpastian musim hujan dan musim kemarau, kenaikan muka air laut yang mengancam wilayah pesisir, serta munculnya berbagai bencana yang diakibatkan oleh iklim (climatic hazards).

Perubahan iklim didefinisikan sebagai perubahan pada iklim yang dipengaruhi langsung atau tidak langsung oleh aktivitas manusia yang merubah komposisi atmosfer, yang akan memperbesar keragaman iklim teramati pada periode yang cukup panjang [2]. Dampak dari perubahan iklim dan pemanasan global yang paling dirasakan oleh negara kepulauan adalah terjadinya kenaikan muka air laut (sea level rise).

Salah satu penyebab terbesar dalam kenaikan muka air laut adalah peningkatan temperatur air laut yang menyebabkan terjadinya pemuaian terhadap volume air laut sehingga massa air laut berubah dan meningkat [3]. Selain itu, mencairnya glasier pegunungan dan tutupan es juga diprediksikan akan menjadi penyebab utama kenaikan muka air laut.

B. Pengumpulan Data

Data-data yang diperlukan untuk pengerjaan tugas akhir ini antara lain terdiri dari data pasang surut, data temperatur, data curah hujan, data jumlah penduduk dan data kualitas udara Kabupaten Tuban. Data pasang surut yang digunakan dalam analisa Tugas Akhir ini adalah data adopsi dari data pasang surut Semarang tahun 1985-2012. Untuk data temperatur menggunakan data temperatur yang diperoleh dari BMKG Tanjung Perak Surabaya tahun 2000 dan 2010, sedangkan data curah hujan menggunakan data curah hujan Kabupaten Tuban tahun 2010 yang diperoleh dari BMKG.

C. Pengolahan Data Pasang Surut

Pada penelitian ini pengolahan data pasang surut menggunakan metode least square untuk mendapatkan MSL. Least square method adalah sebuah metode analisa data pasang surut dengan pendekatan fungsi sinus dan cosinus yang menghasilkan output antara lain yaitu komponen-komponen pasang surut, tipe pasang surut, serta besar MSL (mean sea level). Pengolahan data pasang surut pada metode least square ini melalui program Fortran. Berikut ini adalah persamaan untuk metode least square:

$$\underbrace{\{F\}}_{(2k+1)\times 1} = \underbrace{[H]}_{(2k+1)\times(2k+1)} \underbrace{\{X\}}_{(2k+1)\times 1} \quad (1)$$

Dimana dengan memasukkan komponen matriksnya didapat bentuk persamaan matriks sebagai berikut,

$$\begin{bmatrix} \sum_{t=1}^{m} \eta(t)Cos(\omega_1 t) \\ \vdots \\ \sum_{t=1}^{m} \eta(t)Cos(\omega_{k+1} t) \\ \sum_{t=1}^{m} \eta(t)Sin(\omega_1 t) \\ \vdots \\ \sum_{t=1}^{m} \eta(t)Sin(\omega_k t) \end{bmatrix} = \begin{bmatrix} cc_{1,1} & \cdots & cc_{k+1,1} & sc_{1,1} & \cdots & sc_{k,1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ cc_{1,k+1} & \cdots & cc_{k+1,k+1} & sc_{1,k+1} & \cdots & sc_{k,k+1} \\ cs_{1,1} & \cdots & cs_{k+1,1} & ss_{1,1} & \cdots & ss_{k,1} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ cs_{1,k} & \cdots & cs_{k+1,k} & ss_{1,k} & \cdots & ss_{k,k} \end{bmatrix} \times \begin{bmatrix} A_1 \\ \vdots \\ A_{k+1} \\ B_1 \\ \vdots \\ B_k \end{bmatrix} \quad (2)$$

Dari meng-invers matriks H, maka akan diperoleh komponen-komponen pasang surut yang diperoleh dari matriks X [4].

D. Pemodelan dengan MAGICC

Pada tahap ini dilakukan pemodelan dengan menggunakan MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change). MAGICC adalah tool yang mengintegrasikan model siklus gas, iklim dan pencairan es yang memperkenankan user mendapatkan suhu global rata-rata dan level muka laut akibat dari emisi GRK dan SO2 dengan tujuan untuk membandingkan skenario emisi kebijakan terhadap skenario referensi (efektivitas kontrol kebijakan emisi relatif terhadap baseline kebijakan non- iklim) [5]. Software ini membutuhkan input data yang berupa scenario emisi gas-gas yang telah ditetapkan sebelumnya pada SRES (Special Report on Emissions Scenarios) emisi antropogenik antara lain yaitu CO2, CH4, N2O, SO2, halokarbon dan gas-gas reaktif yang lain. Untuk penelitian ini digunakan skenario B2AIM dan A2AIM yang memiliki pendekatan regional dan parameter model yang digunakan adalah CSIRO. Hasil keluaran dari software MAGICC adalah memberikan informasi proyeksi mengenai temperature global rata-rata dan perubahan permukaan air laut

E. Pemodelan dengan SCENGEN

Setelah pemodelan dengan menggunakan MAGICC selesai maka dihasilkan pemodelan dengan menggunakan SCENGEN. Pada pemodelan dengan SCENGEN dipilih salah satu parameter model yang ada. SCENGEN menghasilkan pola perubahan spasial berupa presipitasi dan perubahan temperatur regional.

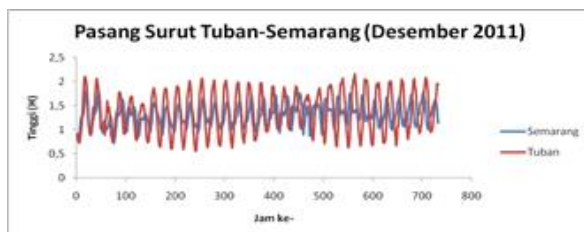
F. Validasi Output

Pada tahap ini dilakukan validasi hasil pemodelan dari MAGICC dan SCENGEN yang dibandingkan dengan data temperatur, pasang surut, serta curah hujan. Selain itu untuk mengetahui daerah yang tergenang akibat terjadinya kenaikan muka air laut maka dilakukan pengolahan data DEM dengan menggunakan software Er Mapper sehingga bisa diketahui daerah mana yang akan tergenang akibat terjadi kenaikan muka air laut.

III. ANALISA DAN PEMBAHASAN

A. Analisa Data Pasang Surut

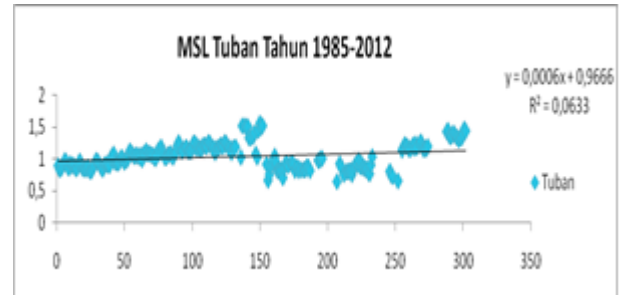
Karena keterbatasan data pasang surut Kabupaten Tuban, maka untuk memprediksi kenaikan muka air laut digunakan data adopsi dari data pasang surut Semarang.

Berdasarkan data pasang surut yang ada yaitu tahun 2011 dan tahun 2012 (Januari-Februari) untuk Kabupaten Tuban dan tahun 1985 sampai tahun 2012 (Januari-Februari) untuk Semarang yang diperoleh dari BAKOSURTANAL, maka dapat ditentukan tipe dari pasang surut Kabupaten Tuban dengan menggunakan metode least square[14]. Dan dari hasil pengolahan ternyata diketahui tipe pasang surut di Kabupaten Tuban dan Semarang adalah mixed diurnal tide.

Gambar 2. Perbandingan pasang surut Semarang dan Tuban bulan Desember 2011

Dari gambar tampak bahwa data pasang surut Kabupaten Tuban memiliki nilai yang lebih tinggi dari data pasang surut Semarang, oleh karena itu perlu di cari nilai untuk mencari nilai baru pasang surut Semarang agar bisa dijadikan adopsi untuk mencari MSL Kabupaten Tuban.

Tabel 1. Mencari Nilai Selisih MSL Semarang dan Tuban

Bulan ke -	MSL Tuban	MSL Semarang	Selisih	MSL Semarang + selisih
289		1.36		1.3600
290		1.27		1.2700
291	1.37	1.26	0.11	1.2600
292	1.39	1.28	0.11	1.2800
293	1.42	1.32	0.1	1.3200
294	1.38	1.29	0.09	1.2900
295	1.34	1.26	0.08	1.2600
296	1.31	1.24	0.07	1.2400
297	1.28	1.21	0.07	1.2100
298	1.32	1.25	0.07	1.2500
299	1.31	1.24	0.07	1.2400
300	1.36	1.31	0.05	1.3100
301	1.46	1.38	0.08	1.3800
302	1.42	1.35	0.07	1.3500
RATA-RATA			0.08083	

Dari selisih tersebut maka bisa diperoleh MSL baru yang akan digunakan untuk memprediksi MSL di Kabupaten Tuban beberapa tahun mendatang.

Gambar 3. MSL Tuban Tahun 1985-2012

Dengan menggunakan persamaan $y=0.0006x+0.9666$ maka dapat diprediksi kenaikan muka air laut Tuban untuk 50 tahun ke depan.

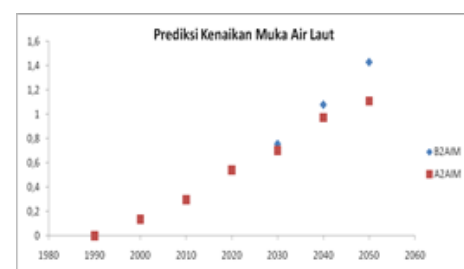
Tabel 2. Prediksi Kenaikan Muka Air Laut

Tahun	Kenaikan Muka Air Laut
2020	1.211
2030	1.283
2040	1.355
2050	1.427

B. Prediksi Kenaikan Muka Air Laut

Untuk memprediksi kenaikan muka air laut di pesisir Kabupaten Tuban menggunakan MAGICC. Dari data statistik yang ada (data statistika penduduk dan data kualitas udara) maka skenario yang paling sesuai dengan kondisi pesisir Kabupaten Tuban adalah Skenario A2 dan B2 yang lebih berorientasi ke skala regional. Dari pemodelan MAGICC diperoleh proyeksi kenaikan muka air laut selama beberapa tahun ke depan sampai tahun 2050 untuk kawasan pesisir Kabupaten Tuban.

Tabel 3. Prediksi Kenaikan Muka Air Laut Berdasarkan Skenario B2AIM dan A2AIM

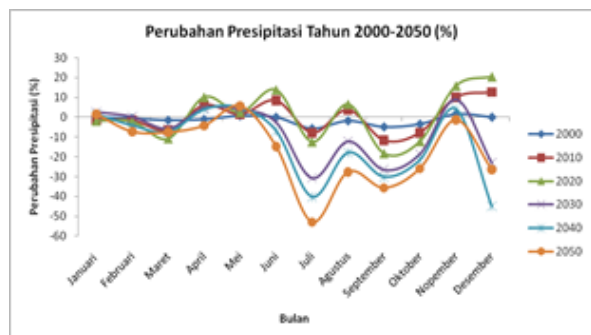
Tahun	Kenaikan Muka Air Laut (m)	
	B2AIM	A2AIM
1990	0.000	0.000
2000	0.135	0.135
2010	0.297	0.297
2020	0.540	0.540
2030	0.757	0.702
2040	1.080	0.973
2050	1.430	1.108

Gambar 4. Kenaikan Muka Air Laut dari tahun 1990-2050

C. Prediksi Perubahan Curah Hujan

Untuk prediksi perubahan curah hujan yang terjadi di pesisir Kabupaten Tuban menggunakan software SCENGEN.Berikut ini adalah hasil proyeksi perubahan presipitasi untuk Kabupaten Tuban. Untuk pemodalan perubahan presipitasi Kabupaten Tuban menempati grid 7.5^{0}-5.0^{0}LS dan 110.0^{0}-112.5^{0}BT. Skenario iklim: B2AIM dan A2AIM, model: CSIRO with aerosol effect.

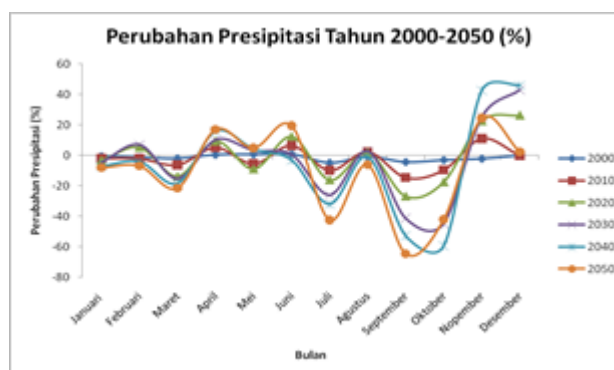
- B2AIM

Tabel 4. Perubahan Presipitasi Perbulan (Skenario B2AIM)

Bulan	Perubahan Presipitasi Perbulan dalam 50 tahun (%)					
	2000	2010	2020	2030	2040	2050
Jan	0	-1.4	-1.8	2.7	1.4	1.5
Feb	-0.6	-1.6	-2.2	0.3	-4.2	-7.3
Mar	-1.5	-6.7	-10.8	-5.7	-7.5	-7.6
Apr	-1.1	6.2	10.2	4.6	3.9	-4.2
Mei	0.7	1.5	2.5	4.1	4.8	5.7
Jun	0	8.5	13.9	-2.5	-6.9	-14.8
Jul	-5.6	-7.9	-12.4	-30.7	-40.2	-53
Ags	-1.8	3.8	6.6	-12.1	-17.9	-27.6
Sep	-4.8	-11.7	-18.3	-26.5	-30.1	-35.7
Okt	-3.4	-7.8	-12.2	-18.5	-21.5	-25.9
Nop	1.5	10.1	15.9	9	4.1	-1.3
Des	0	12.7	20.6	-23	-45	-26.4

Gambar 5. Pola Perubahan Presipitasi Selama 50 tahun (Skenario B2AIM)

- A2AIM

Tabel 5. Perubahan Presipitasi Perbulan (Skenario A2AIM)

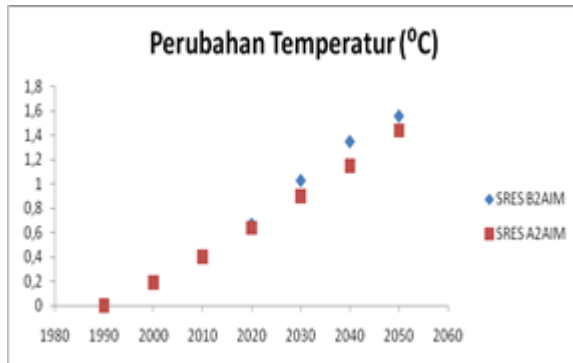
Bulan	Perubahan Presipitasi Perbulan dalam 50 tahun (%)					
	2000	2010	2020	2030	2040	2050
Jan	-0.5	-2	-3.3	-4.6	-7.3	-8.1
Feb	-1.3	-2.1	5.3	7	-4.2	-6.9
Mar	-2	-6.2	-13.7	-15.3	-18.5	-21.5
Apr	0.4	5.2	9.4	10.2	15.8	17
Mei	0.6	-5.5	-8.9	3.3	4.1	4.9
Jun	0.8	6.5	12.4	0.5	-3.2	19.5
Jul	-4.9	-9.8	-16.1	-26.1	-32	-42.4
AgS	-0.9	2.4	1.8	2.7	-1	-6.1
Sep	-4.4	-14.6	-26.8	-41.4	-52.9	-64.6
Okt	-3.1	-9.6	-17.4	-44.8	-59.4	-42
Nop	-2.2	11.1	22.6	25.2	42.5	24.4
Des	-0.1	-0.1	26.4	42.9	45.9	2.3

Gambar 6. Pola Perubahan Presipitasi Selama 50 tahun (Skenario A2AIM)

Dari hasil pemodelan dengan SCENGEN dengan menggunakan dua skenario diketahui bahwa terjadi pola perubahan presipitasi yang cukup besar pada bulan Juli, Agustus, September dan Oktober.

D. Prediksi Perubahan Temperatur

Untuk prediksi perubahan temperatur yang terjadi di pesisir Kabupaten Tuban menggunakan software SCENGEN.Berikut ini adalah hasil proyeksi perubahan temperatur untuk Kabupaten Tuban. Untuk pemodalan perubahan temperatur Kabupaten Tuban menempati grid 7.5^{0}-5.0^{0}LS dan 110.0^{0}-112.5^{0}BT. Skenario iklim: B2AIM dan A2AIM, model: CSIRO with aerosol effect. Berikut ini adalah proyeksi kenaikan temperatur regional.

Tabel 6. Kenaikan Temperatur Regional

Tahun	Perubahan Temperatur (^{0}C)	
	B2AIM	A2AIM
1990	0	0
2000	0.19	0.19
2010	0.41	0.4
2020	0.67	0.64
2030	1.03	0.9
2040	1.35	1.15
2050	1.56	1.44
Rata-rata	0.74428571	0.67428571

Gambar 7. Prediksi Kenaikan Temperatur

E. Validasi Hasil Pemodelan dengan Data Lingkungan

- Validasi Kenaikan Muka Air Laut

Untuk membandingkan prediksi kenaikan muka air laut antara hasil pemodelan MAGICC dengan MSL Tuban, maka diasumsikan bahwa MSL Kabupaten Tuban pada tahun 1990 adalah 0 (sebagai acuan awal kenaikan muka air laut). Dan berikut ini adalah perbandingan prediksi kenaikan muka air laut Tuban antara hasil pemodelan menggunakan MAGICC dan hasil prediksi MSL Tuban.

Tabel 7. Perbandingan Kenaikan Muka Air Laut Hasil Pemodelan dan MSL Tuban

Tahun	Kenaikan Muka Air Laut (m)			Koreksi (%)	
	B2AIM	A2AIM	MSL Tuban	B2AIM	A2AIM
1990	0	0	0	0	0
2000	0.135	0.135	0.86	-5.37037	-5.37037
2010	0.297	0.297	1.02	-2.43434	-2.434343
2020	0.54	0.54	1.2114	-1.24333	-1.243333
2030	0.757	0.702	1.2834	-0.69538	-0.828205
2040	1.08	0.973	1.3554	-0.255	-0.393011
2050	1.43	1.108	1.4274	0.001818	-0.288267
Rata-rata	0.60557	0.53643	1.0225143	-1.42809	-1.759588

Gambar 8. Validasi kenaikan muka air laut antara pemodelan dengan MSL

Dari grafik dapat dilihat bahwa kenaikan muka air berdasarkan prediksi kenaikan MSL dari tahun 1990-2050 memiliki nilai yang hampir sama dengan nilai dari hasil pemodelan MAGICC dengan skenario B2AIM dibandingkan dengan skenario A2AIM yaitu terjadi kenaikan muka air laut sebesar 1.43 meter. Untuk tahun 1990 kenaikan muka air laut. Dari prediksi kenaikan MSL Kabupaten Tuban akan terjadi kenaikan muka air laut sebesar 1.21 meter pada tahun 2020, 1.24 meter pada tahun 2030, 1.35 meter pada tahun 2040, dan 1.43 meter pada tahun 2050. Sedangkan untuk prediksi kenaikan muka air laut dengan skenario B2AIM akan terjadi kenaikan muka air laut sebesar 0.54 meter pada tahun 2020, 0.78 meter pada tahun 2030, 1.08 meter pada tahun 2040, dan 1.43 meter pada tahun 2050.

- Validasi Perubahan Presipitasi

Untuk koreksi perubahan presipitasi dari pemodelan SCENGEN menggunakan data curah hujan Kabupaten Tuban tahun 2010 yang diperoleh dari BPS Kabupaten Tuban. Untuk menentukan curah hujan yang terjadi berdasarkan hasil dari pemodelan maka digunakan persamaan berikut:

$$\text{CH akan datang} = \text{data observasi} + (\text{data observasi x } \frac{\%\, perubahan}{100})$$

Data observasi yang digunakan dalam penelitian ini adalah data curah hujan bulanan Kabupaten Tuban tahun 2010. Dan prosentase perubahan curah hujan diperoleh dari hasil pemodelan SCENGEN yang telah dijelaskan pada pembahasan sebelumnya.

Tabel 8. Perbandingan curah hujan data observasi dan model

Bulan	Dt. Obs	%Perubahan		CH akan datang (mm		Faktor Koreksi %	
		B2AIM	A2AIM	B2AIM	A2AIM	B2AIM	A2AIM
Jan	316.08	-1.4	-2	311.655	309.758	-0.0142	-0.0204
Feb	240.48	-1.6	-2.1	236.632	235.43	-0.01626	-0.0215
Mar	32.96	-6.7	-6.2	30.7517	30.9165	-0.07181	-0.0661
Apr	248.96	6.2	5.2	264.396	261.906	0.05838	0.04943
Mei	176.68	1.5	-5.5	179.33	166.963	0.014778	-0.0582
Jun	113.32	8.5	6.5	122.952	120.686	0.078341	0.06103
Jul	144.8	-7.9	-9.8	133.361	130.61	-0.08578	-0.1086
Ags	51.84	3.8	2.4	53.8099	53.0842	0.036609	0.02344
Sep	154.56	-11.7	-14.6	136.476	131.994	-0.1325	-0.171
Okt	191.08	-7.8	-9.6	176.176	172.736	-0.0846	-0.1062
Nop	155.72	10.1	11.1	171.448	173.005	0.091735	0.09991
Des	251	12.7	-0.1	282.877	250.749	0.112689	-0.001
rata-rata						-0.00105	-0.0266

- **Validasi Perubahan Temperatur**

Untuk validasi perubahan temperatur dari pemodelan SCENGEN menggunakan data temperatur yang diperoleh dari BMKG Tanjung Perak Tahun 2000 dan 2010. Berikut ini adalah selisih perubahan temperatur antara perubahan temperatur global dengan perubahan temperatur regional. Untuk menghitung selisih perubahannya menggunakan persamaan:

Selisih Perubahan = Suhu Proyeksi - Suhu Baseline

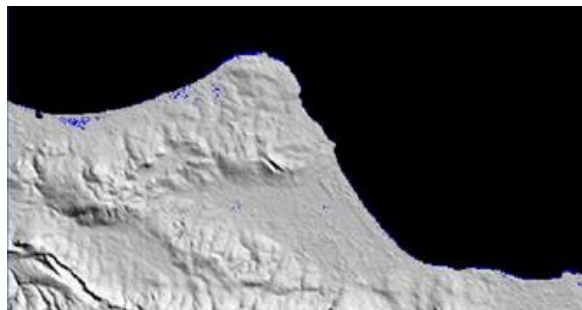
Tahun	Perubahan T (^{0}C)		T Global (^{0}C)		Selisih(^{0}C)	
	B2AIM	A2AIM	B2AIM	A2AIM	B2AIM	A2AIM
1990	0	0	0	0	0	0
2000	0.19	0.19	0.17	0.17	0.02	0.02
2010	0.41	0.4	0.35	0.33	0.06	0.07
2020	0.67	0.64	0.56	0.5	0.11	0.14
2030	1.03	0.9	0.83	0.65	0.2	0.25
2040	1.35	1.15	1.16	0.89	0.19	0.26
2050	1.56	1.44	1.5	1.15	0.06	0.29

Selisih perubahan temperatur digunakan untuk mengetahui besar temperatur yang terjadi dan kemudian dibandingkan dengan data lingkungan yang ada.

Suhu akan datang = Suhu Observasi + Selisih Perubahan

Tahun	T Obs (^{0}C)	Selisih (^{0}C)		T akan Datang (^{0}C)		Faktor Koreksi %	
		B2AIM	A2AIM	B2AIM	A2AIM	B2AIM	A2AIM
1990	0	0	0	0	0	0	0
2000	27.3528	0.02	0.02	27.373	27.373	0.0007	0.0007
2010	28.8581	0.06	0.07	28.918	28.928	0.0021	0.0024
2020	-	0.11	0.14	-	-	-	-
2030	-	0.2	0.25	-	-	-	-
2040	-	0.19	0.26	-	-	-	-
2050	-	0.06	0.29	-	-	-	-

F. Pembuatan Visualisasi Daerah Genangan

Pembuatan visualisasi genangan daerah pesisir yang tergenang akibat kenaikan muka air laut di Kabupaten Tuban ini menggunakan data DEM darat dan citra LANDSAT. Dengan menggunakan tools Land Application Wizard pada software ER Mapper.

Gambar 9. Data DEM yang hasil output dari ER Mapper

Gambar 10. Visualisasi Daerah Genangan di Pesisir Kabupaten Tuban Akibat Kenaikan Muka Air Laut

IV. KESIMPULAN / RINGKASAN

Dari hasil analisa pembahasan diatas tentang skenario perubahan iklim untuk daerah pesisir Kabupaten Tuban dengan membandingkan dua skenario yang berbeda yaitu skenario A2AIM dan skenario B2AIM, maka dapat diambil kesimpulan bahwa skenario yang sesuai dengan kondisi daerah pesisir Kabupaten Tuban adalah skenario B2AIM yang menghasilkan proyeksi kenaikan muka air laut sebesar 0.135 m pada tahun 2000, 0.297 m untuk tahun 2010, 0.54 m pada tahun 2020, 0.757 m pada tahun 2030, 1.08 m pada tahun 2040 dan 1.43 m pada tahun 2050. Dari hasil analisa juga diketahui bahwa terjadi perubahan curah hujan yang cukup besar pada bulan Juli, Agustus, September dan Oktober. Dan untuk perubahan temperatur yaitu sebesar 0.19^{0}C pada tahun 2000, 0.41^{0}C pada tahun 2010, 0.67^{0}C pada tahun 2020, 1.03^{0}C pada tahun 2030, 1.35^{0}C pada tahun 2040, dan 1.56^{0}C pada tahun 2050.

UCAPAN TERIMA KASIH

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Study on the Distribution of Seawater Influence to the Coastal Groundwater in Eastern Surabaya Coastal Area

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Abstract – *We have measured the salinity and concentrations of nutrients (nitrite, nitrate, amonia, and phosphate) of the coastal groundwater in East Surabaya Coastal Areas to observe its distribution and to estimate the possibility as a source of brakish water for aquaculture. Measurement of groundwater salinity were conducted insitu in 48 locations of shalow dig well, and the nutrients concentration were measured in the Laboratory of Environment of the Department of Environmental Engineering, ITS Surabaya. In order to avoid the influence of seawater level fluctuation to the salt and nutrient concentrations of coastal groundwater, collection of water samples were done during the neap tide period. The results show that, generally the degree of salinity is landward decrease, and vice versa. The different trends are shown in the distribution of nutrients in the groundwater, reveals that there are no correlation between pattern of distribution of nutrients concentration with their distance to the coastline. Based on the water quality of the graoundwater in the eastern Surabaya coastal area, it is possible to utilize the groundwater to be used as a source of water for the brakish water aquaculture. According to the level and its distribution of the salinity of the groundwater, it is concluded that there is no indication of seawater intrution in the study area.*

Keywords **:** *eastern Surabaya coastal area, nutrients, seawater influence.*

1. PENDAHULUAN

Air merupakan komponen paling penting dalam kehidupan, termasuk apalagi bagi organisme yang hidup di air seperti ikan. Bagi organisme yang hidup di dalamnya, air tidak hanya sekedar media tempatnya hidup, tetapi juga sebagai media yang menyediakan oksigen, nutrisi, dan komponen lain yang dibutuhkan untuk hidup dan berkembang. Faktor penting dari karakteristik air yang dibutuhkan untuk budidaya perikanan antara lain adalah suhu, salinitas, oksigen terlarut, derajad keasaman, alkalinitas, amonia, nitrit, nitrat, asam sulfida, karbon dioksida, dan besi (Udi Putra, 2011).

Berkaitan dengan air, penduduk di wilayah pesisir Surabaya timur mempunyai permasalahan mengenai ketersediaan dan kualitas air untuk kebutuhan sehari-harinya. Kualitas air tanah yang payau tidak memungkinkan untuk dimanfaatkan sebagai air baku pertanian, air bersih, apalagi untuk air minum. Tetapi ketersediaan air tanah yang payau memunghkinkan untuk dimafaatkan sebagai sumber air untuk perikanan air payau. Lokasi lahan yang jauh dari jangkauan air pasang, sehingga tidak memungkinkan menangkap air laut untuk media budidaya perikanan. Untuk mengetahui potensi air tanah untuk budidaya perikanan air payau maka perlu dilakukan studi pengaruh air laut terhadap air tanah di pesisir Surabaya timur.

Makalah ini menyajikan hasil studi terhadap air tanah di pesisir Surabaya timur. Studi dilakukan terhadap kualitas air tanah yang meliputi salinitas, kandungan nitrit, nitrat, amonia, dan fosfat. Tujuan studi ini adalah untuk mengetahui pola distribusi salinitas dan parameter kualitas tersebut di atas, dan mengetahui kemungkinan pemanfaatan air tanah untuk budidaya perikanan ikan payau, serta mengetahui pengaruh air laut terhadap air tanah dangkal.

2. DASAR TEORI

2.1. Air Tanah

Sampel air yang digunakan dalam penelitian ini adalah air tanah bebas dari sumur penduduk. Air tanah

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adalah semua air yang terdapat di dalam lapisan tanah atau batuan di bawah permukaan tanah pada zona jenuh air. Muka air tanah bebas atau muka freatik adalah muka air tanah pada akuifer tidak tertekan. Akuifer adalah lapisan batuan jenuh air di bawah permukaan tanah yang dapat menyimpan dan meneruskan air. Air tanah tidak tertekan atau air tanah bebas adalah air tanah yang terdapat di dalam akuifer tidak tertekan (BSN, 2005).

2.2. Salinitas

Air laut merupakan campuran kompleks dari air dan garam (mineral yang larut) yang konsentrasinya 3,5% dari air laut. Berapa besar kandungan atau konsentrasi garam dalam air diukur dengan salinitas. Sehingga salinitas adalah proporsi dari garam yang larut terhadap air murni. Biasanya diekspresikan dengan pph (part per hundred, atau persen). Tetapi karena konsentrasi garam dalam air laut rendah, biasa juga dalam ppt (part per thousand). Salinitas lautan bervariasi tergantung pada jumlah air tawar yang masuk kedalam sistem lautan dan jumlah evaporasi yang terjadi. Jika terjadi evaporasi sangat banyak, maka air laut menjadi lebih asin karena evaporasi terjadi lebih cepat dibanding tambahan air tawar. Sehingga banyak garam tertinggal dalam air laut. Sebaliknya lebih banyak tambahan air tawar kedalam sistem, salinitas lautan rendah.

Di daerah transisi seperti estuari, delta, perairan pantai mulut sungai dan sebagian besar daerah pesisir yang berdekatan dengan garis pantai mempunyai salinitas yang berkisar di antara air tawar dan air laut. Komponen utama garam dalam air laut ditunjukkan pada Tabel 1.

Tabel 1. Komponen utama garam yang menyusun air laut

No	Garam	Konsentrasi (ppt)
1	NaCl (halit)	23.48 (2.35%)
2	$MgCl_2$	4.98 (0.50%)
3	Na_2SO_4	3.92
4	$CaCl_2$	1.10
5	KCl	0.66
6	$NaHCO_3$ (Sodium bikarbonat)	0.192
7	KBr	0.096
8	H_3BO_3 (Hidrogen borat)	0.026

Semua air mengandung material kimia terlarut. Tingkat konsentrasi yang tinggi menyebabkan air menjadi asin ataupun payau. Perbedaan antara air tawar dengan air asin ditentukan oleh tingkat salinitas (keasinan), yang ditunjukkan pada pers (1).

Salinitas (ppt) = berat mineral terlarut dalam garam : 1 kg air laut x 1000 (1)

Karena NaCl merupakan mineral terlarut mineral terlarut yang dominan pada air laut, maka pengukuran jumlah ion Cloride dapat digunakan untuk menentukan salinitas. (Lewis, 1980)

Salinitas = 1,80655 x klorinitas (2)

Pada Peraturan Menteri Kesehatan RI nomor 907 Tahun 2002, batas maksimum kandungan klorida untuk air minum adalah 250 mg/L dan 500 mg/L untuk air bersih. Ambang rasa asin yang dapat diterima oleh manusia untuk air minum berkisar 600 mg/L klorida. Kandungan material terlarut dalam air laut pada kadar garam 35 ppt dapat ditunjukkan pada Table 2.

Tabel 2. Komponen terlarut dalam air laut dengan kadar garam 35 ppt.

Komponen	Konsentrasi (mg/L)
Klorida	19.000
Sodium	10.500
Sulfat	2.700
Magnesium	1.350
Kalsium	410
Potasium	390
Bikarbonat	142
Bromida	67
Strontium	8
Silika	6,4
Boron	4,5
Fluorida	1,3

2.3. Kandungan N-Nitrit (N-NO_2) dalam air tanah

Nitrit dalam air dapat berasal hasil reaksi oksidasi amonia oleh bakteri nitrosomonas. Keberadaan nitrit (N-NO_2) menggambarkan berlangsungnya proses biologis perombakan bahan organik yang memiliki kadar oksigen terlarut sangat rendah. Kadar nitrit di perairan relatif kecil karena segera dioksidasi menjadi nitrat. Di perairan alami, kadar nitrit sekitar 0,001 mg/L dan tidak melebihi 0,06 mg/L.

Kadar nitrit yang lebih dari 0,05 mg/L dapat bersifat toksik bagi organisme perairan yang sangat sensitif. Nitrit meracuni ikan dengan mengikat hemoglobin dalam darah mencegah agar tidak membawa oksigen, pada dasarnya menyesakkan ikan. Insang ikan mati akibat keracunan nitrit dengan warna kecoklatan (OATA, 2008). Standar baku mutu nitrit untuk air minum Permenkes No. 416, tahun 1990 adalah tidak boleh lebih dari 1 mg/L.

Nitrit meracuni ikan dengan mengikat hemoglobin dalam darah mencegah agar tidak membawa oksigen, pada dasarnya menyesakkan ikan. Insang ikan mati akibat keracunan nitrit dengan warna kecoklatan (OATA, 2008). Ammonia dalam pengukuran biasanya dalam betuk ammonia total yang terdiri dari Amonium (NH_4) + Ammonia bebas (NH_3). Tingkat amonia bebas lebih dari 0.2 mg/L menyebabkan ikan menjadi stres dan pada tingkat yang lebih tinggi menyebabkan kerusakan insang dan organ internal lainnya yang akan menyebabkan kematian (OATA, 2008).

2.4. Kandungan N-Nitrat (N-NO_3) dalam air tanah

N-Nitrat sangat mudah larut dalam air dan bersifat stabil. Nitrat merupakan bentuk utama nitrogen dalam air dan merupakan nutrien utama bagi pertumbuhan tanaman dan alga (Bahri, 2006). Kadar nitrat di perairan yang tidak tercemar biasanya lebih tinggi dari amonia. Pada perairan yang kaya oksigen nitrogen cenderung berbentuk nitrat, dan sebaliknya nitrogen cenderung berbentuk amonia (Hutagalung & Rozak 1997).

Kadar nitrat yang melebihi 5 mg/L menunjukkan terjadinya pencemaran antropogenik (yang berasal dari aktivitas manusia). Misalnya masuknya limbah permukiman, industri atau limbah pertanian (pemupukan) yang umumnya banyak mengandung nitrat. Standar baku mutu air minum Permenkes No. 416, tahun 1990 adalah tidak boleh lebih dari 10 mg/L

2.5. Amonia

Amonia merupakan hasil dari proses penguraian bahan organik akibat kotoran organisme dan aktivitas jasad renik dalam proses dekomposisi bahan organik yang kaya akan nitrogen. Biasanya dalam betuk amonia total yang terdiri dari amonia berion (NH_4) dan amonia bebas (NH_3). Amonia berion tidak beracun, sedangkan amonia bebas bersifat racun.

Tingkat peracunan amonia berion berbeda-beda untuk tiap spesies, tetapi pada 0,6 mg/L dapat membahayakan (Boyd, 1982). OATA (2008): konsentrasi NH_3 > 0,2 mg/L menyebabkan ikan menjadi stres dan pada tingkat yang lebih tinggi menyebabkan kerusakan insang dan organ internal lainnya yang akan menyebabkan kematian pada ikan.

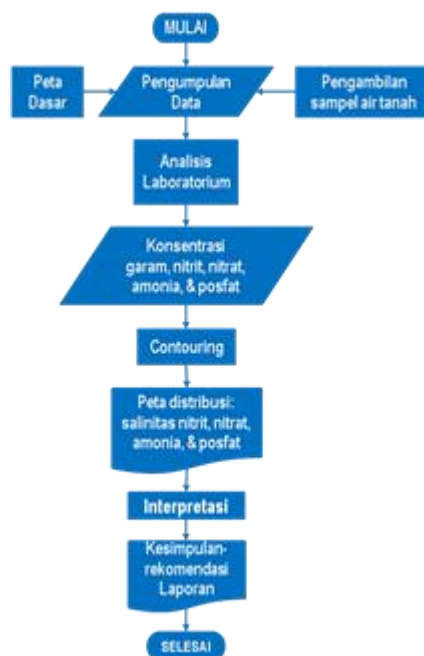
2.6. Total PO_4 sebagai P

Fosfat adalah bentuk fosfor yang dapat dimanfaatkan oleh tumbuhan dan merupakan unsur esensial bagi tumbuhan tingkat tinggi dan alga sehingga dapat mempengaruhi tingkat produktivitas perairan (Bahri, 2006). Perairan yang mengandung fosfat tinggi kemungkinan telah mengalami pencemaran limbah organik dari permukiman atau dari industri.

Ambang baku fosfat untuk budidaya ikan adalah 1 mg/L (OATA, 2008). Pada konsentrasi yang lebih tinggi menyebabkan kerusakan insang dan organ internal lainnya yang akan menyebabkan kematian pada ikan (OATA, 2008).

3. METODOLOGI

Penelitian ini dilakukan dengan mengambil sampel air tanah dari sumur penduduk di wilayah pesisir Surabaya timur (Gambar 1). Dalam pengambilan sampel air tanah digunakan peta dasar Peta Rupa Bumi, dan GPS untuk menentukan posisi, koordinat dan elevasi titik pengambilan sampel. Selain mengambil sampel air, dilakukan pula pengukuran kedalaman muka air tanah.

Sampel air yang tanah diambil kemudian dianalisis, diukur kadar salinitasnya, konsentrasi Nitrogen-NO_2, Nitrogen-NO_3, Nitrogen-NH_3, dan PO_4 di Laboratorium Lingkungan Jurusan Teknik Lingkungan, FTSP-ITS Surabaya. Langkah penelitian diringkas dalam diagram alir dan disajikan pada Gambar 2.

Gambar 2. Diagram alir tahap penelitian

4. HASIL DAN PEMBAHASAN

Daerah studi di pesisir kota Surabaya bagian timur mempunyai elevasi antara 3 m sampai 5 m, dengan topografi rata dan kemiringan kecil hampir landai (1:1000). Pesisir Surabaya bagian timur tersusun oleh sedimen aluvial, belum kompak sampai lepas, campuran pasir, lanau, lempung. Elevasi muka air tanah berkisar antara 0,5 m sampai 2,5 m di atas muka air laut. Penduduk memanfaatkan air tanah bebas (dari sumur gali) untuk kebutuhan air bersih (MCK).

Dalam penelitian ini sampel air tanah di pesisir Surabaya timur telah diambil dari 48 lokasi (Gambar 3) dan telah dilakukan pengukuran salinitas serta konsentrasi nitrit, nitrat, amonia, dan posfat. Pengukuran dilakukan di Laboratorium Lingkungan

Jurusan Teknik Lingkungan, FTSP-ITS Surabaya. Hasil pengukuran disajikan pada Tabel 3 dan Gambar 3 sampai 7.

Tabel 3. Sebagian dari hasil pengukuran sampel air tanah dari wilayah pesisir Surabaya timur

No	Kode Sampel (nomor lokasi)	Salinitas (ppt)	Nitrit (mg/L NO_2-N)	Nitrat (mg/L NO_3-N)	Amonia (mg/L NH_3-N)	Pospat (mg/L PO_4-P)
1	1	39,10	0,04	4,25	7,90	0,95
2	10	19,10	4,86	10,80	0,00	0,10
3	17	2,53	0,06	5,53	0,50	1,14
4	21	5,14	0,00	1,11	0,45	2,37
5	32	4,39	0,00	6,44	0,00	0,48
6	33	6,90	0,00	1,16	0,00	0,18
7	34	5,44	0,00	6,79	0,00	2,16
8	44	8,50	0,00	1,92	0,00	0,26
9	50	2,87	0,00	8,62	0,40	0,74
10	78	0,95	0,01	4,14	0,38	0,86

4.1. Distribusi Salinitas, Nitrit, Nitrat, Amonia, dan Fosfat dalam Air Tanah di Pesisir Surabaya Timur

Secara umum kadar garam dalam air tanah semakin rendah kearah daratan atau semakin menjauh dari garis pantai (Gambar 4). Nilai kadar garam berkisar dari 0,4 ppt sampai 0,8 ppt ditemukan di bagian barat daerah studi. Semakin kearah laut kadar garam meningkat dari 2 ppt sampai 8 ppt di bagian tengah daerah studi, dan semakin kearah utara kenaikan kadar garam semakin tinggi pada kisaran 20-32 ppt di bagian timur laut pesisir Surabaya.

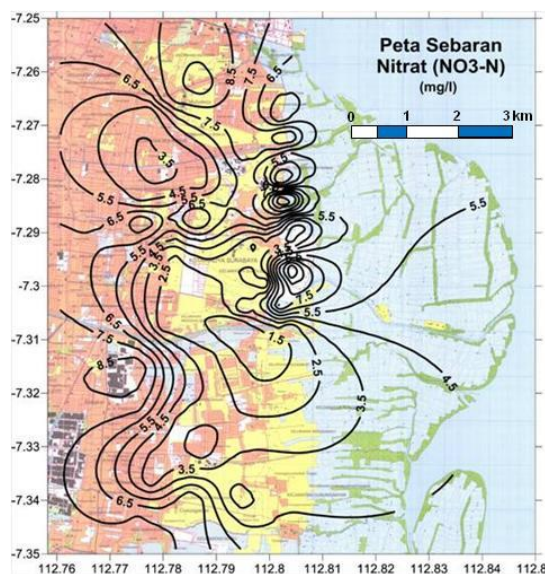
Berdasarkan kadar garam, air tanah di wilayah Surabaya timur tidak layak untuk air minum, tetapi aman untuk budidaya perikanan air payau.

Gambar 3. Peta lokasi pengambilan sampel air tanah

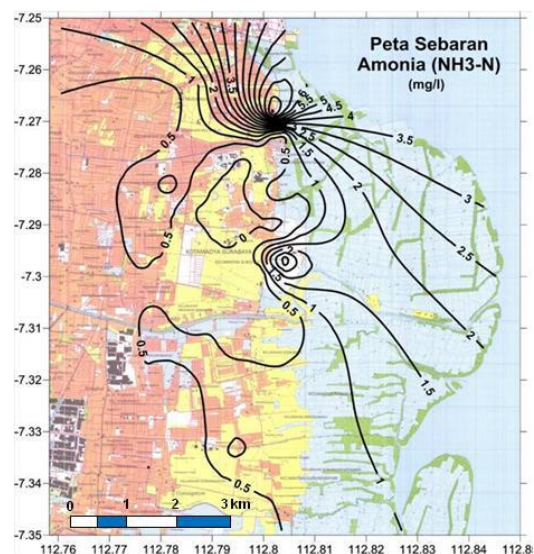
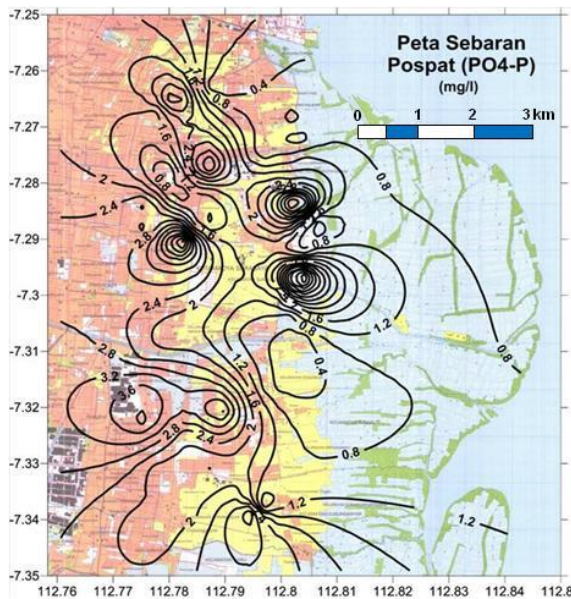
Distribusi konsentrasi nitrat dalam air tanah di peisisir Surabaya timur disajikan pada Gambar 4. Secara keseluruhan kadar nitrit di dalam air tanah di daerah studi sangat rendah. Kecuali di bagian timur laut daerah studi di daerah Kalisari Damen yang mencapai 12,9 mg/L, ini merupakan kondisi yang tidak biasa. Kemungkinan tidak ada oksigen dan bakteri untuk merubah nitrit menjadi amonia, karena pencemaran limbah organik. Secara umum (terutama di bagian barat), kandungan nitrit dalam air tanah di daerah studi aman sebagai sumber air untuk budidaya perikanan.

Gambar 4. Distribusi salinitas air tanah di Surabaya timur

Gambar 4. Distribusi nitrit dalam air tanah di Surabaya timur

Distribusi konsentrasi nitrat dalam air tanah di pesisir Surabaya bagian timur ditunjukkan pada Gambar 5. Secara umum kandungan nitrat dalam air tanah di pesisir Surabaya timur rendah (berkisar antara 1,5 mg/L sampai 8,5 mg/L). Di beberapa tempat di daerah Rungkut di area industri dan di bagian utara daerah studi di area permukiman, kadar nitrat mencapai 8,5 mg/L. Kemungkinan air tanah di daerah ini telah tercemar oleh limbah rumah tangga dan limbah industri. Secara keseluruhan kadar nitrat di dalam air tanah di daerah studi rendah dan di bawah baku mutu untuk air minum (10 mg/L, Kepmenkes 416, 1990), serta aman untuk budidaya perikanan (< 20 mg/L; OATA, 2008).

Gambar 5. Distribusi nitrat dalam air tanah di Surabaya timur

Konsentrasi amonia dalam air tanah dan distribusinya di pesisir Surabaya timur dapat dilighat pada Gambar 6. Kandungan amonia (NH3) dalam air tanah di pesisir Surabaya berkisar antara 0 mg/L sampai 4,5 mg/L. Secara keseluruhan kadar amonia di dalam air tanah di daerah studi melewati baku mutu untuk budidaya perikanan, yaitu lebih dari 0,5 mg/L (OATA, 2008). Terutama di daerah timur laut daerah studi di Mulyorejo dan Kenjeran. Kemungkinan kandungan zat organik dalam air tanah tinggi, atau sampel tersimpan terlalu lama sebelum dilakukan analisis.

Distribusi konsentrasi fosfat dalam air tanahdi pesisir timur kota Surabaya ditunjukkan pada Gambar 7. Kandungan fosfat (PO4) dalam air tanah di pesisir Surabaya berkisar antara 0,8 mg/L sampai 3,6 mg/L. Secara keseluruhan kadar fosfat semakin tinggi kearah barat daerah studi ke wilayah permukiman. Kandungan fosfat yang tinggi dalam air tanah di bagian barat daerah studi (wilayah permukiman) dan industri, menunjukkan pencemaran air tanah oleh limbah domestik dan industri.

Gambar 6. Distribusi amonia dalam air tanah di Surabaya timur

Gambar 7. Distribusi posfat dalam air tanah di Surabaya timur

4.2. Pengaruh Air Laut terhadap Air Tanah di Pesisir Surabaya Timur

Tidak ada pengaruh intrusi air laut terhadap air tanah. Pengaruh air laut terjadi karena masuknya air laut kedalam akuifer bebas pada saat air pasang. Kemungkinan yang lain permukaan air tanah bebas berhubungan langsung dengan permukaan air sungai yang bercampur dengan air laut, sehingga meningkatkan salinitas air tanah. Atau, sedimen yang menyusun wilayah pesisir Surabaya timur merupakan endapan pantai/rawa/estuari/delta, sehingga secara genetis memang payau.

5. KESIMPULAN

Berdasarkan analisis dan interpretasi data yang diperoleh dapat ditarik beberapa kesimpulan seperti di bawah.

1. Pola sebaran konsentrasi nitrit, nitrat, amonia, dan fosfat dalam air tanah di pesisir Surabaya timur tidak berhubungan dengan pengaruh air laut. Tidak ada kecenderungan semakin dekat dengan garis pantai semakin tinggi konsentrasi.
2. Sangat mungkin dilakukan budidaya perikanan air payau di pesisir Surabaya timur dengan memanfaatkan air tanah, tetapi perlu dilakukan penelitian lanjutan tentang kualitas dan baku mutu air tanah dari parameter yang lain.
3. Tidak ada pengaruh intrusi air laut terhadap air tanah.
4. Pengaruh air laut terjadi karena masuknya air laut pada saat air pasang dan kemungkinan permukaan air tanah bebas berhubungan langsung dengan permukaan air sungai yang bercampur dengan air laut

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15

Identifikasi Faktor – Faktor Yang Mempengaruhi Tingkat Kerentanan Bencana Banjir Rob di Pantai Utara Surabaya

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Abstrak – *Kawasan Pantai Utara Surabaya merupakan kawasan yang sangat rentan terhadap bencana banjir rob. Laju kenaikan air laut di pesisir Kota Surabaya setinggi 5,47 mm per tahun dalam periode waktu 64 tahun (1925-1989). Sebagian besar kawasan ini dimanfaatkan untuk kegiatan industri dan pergudangan, pertanian ladang garam, permukiman, militer dan pelabuhan. Hal ini menyebabkan dampak negatif dari bencana banjir rob akan semakin besar. Oleh karena itu, penelitian terkait kerentanan bencana banjir tersebut sangatlah diperlukan. Penentuan faktor kerentanan sebagai langkah strategis dalam menilai kerentanan menjadi fokus utama dalam paper ini.Penelitian ini menggunakan metode Content Analisis untuk mendapatkan faktor yang berpengaruh terhadap kerentanan bencana banjir rob. Metode content analysis dilakukan pada hasil wawancara mendalam (in-depth interview) kepada enam stakeholders melalui proses purposive sampling. Keenam stakeholders tersebut merepresentasikan pemerintah, masyarakat (civil society) dan swasta. Berdasarkan hasil analisa, ada delapan faktor yang mempengaruhi tingkat kerentanan dari total 27 variabel hasil kajian literatur. Faktor-faktor tersebut adalah tingkat kepadatan penduduk yang tinggi, kawasan dengan topografi yang rendah, berkurangnya kawasan resapan air, pendapatan masyarakat pada sektor rentan, sarana dan prasarana penting, buruknya kondisi saluran drainase, dekatnya dengan wilayah sungai dan kawasan terbangun berada di lahan rawa.*

Keywords **:** *Banjir rob, Kerentanan, Pantai Utara Surabaya.*

1. PENDAHULUAN

Semakin meningkatnya jumlah penduduk disertai dengan meningkatnya kegiatan manusia terutama dalam bidang transportasi dan industri, secara tidak langsung akan memicu kenaikan suhu di seluruh permukaan bumi yang dikenal dengan pemanasan global (Rukaesih, 2004). Menurut Intergovermental Panel on Climate Change (IPCC) (2001) pemanasan global adalah proses peningkatan suhu rata-rata atmosfer, laut dan daratan di bumi yang disebabkan oleh peningkatan konsentrasi gas-gas rumah kaca melalui efek rumah kaca akibat aktivitas manusia terutama polusi dan pencemaran lingkungan seiring dengan pembangunan terus-menerus.

Salah satu dampak dari pemanasan global yang melanda bumi ini adalah kenaikan muka air laut yang dapat menyebabkan hilangnya daratan. Karena pemanasan global menyebabkan banyak permukaan es mencair sehingga menyebabkan volume air laut meningkat, hal ini dapat menenggelamkan daratan yang ada di bumi ini. Laporan dari IPCC memperkirakan bahwa pada kurun waktu 100 tahun terhitung mulai tahun 2000 permukaan air laut akan meningkat setinggi 15-90 cm dengan kepastian peningkatan setinggi 48 cm (Mimura, 2000). Kenaikan muka air laut tersebut menyebabkan meningkatkan skala dan frekuensi banjir rob di pesisir pantai.

Kawasan pesisir utara Surabaya merupakan wilayah yang sebagian besar dimanfaatkan untuk kegiatan industri dan pergudangan, pertanian ladang garam, permukiman, militer dan pelabuhan (RZWP Kota Surabaya, 2011). Sedangkan berdasarkan hasil dari penelitian yang dilakukan oleh Meiviana (2004) memperlihatkan laju kenaikan air laut di pesisir Kota Surabaya setinggi 5,47 mm per tahun dalam periode

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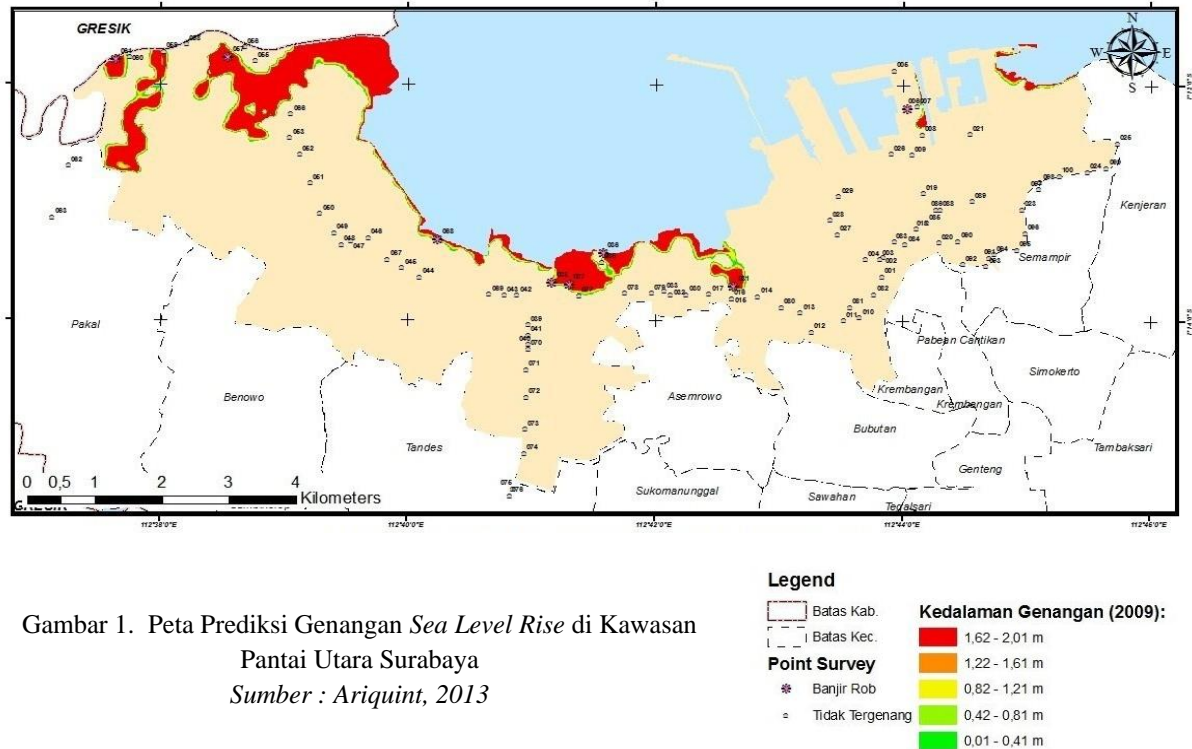
waktu 64 tahun (1925-1989). Pada bulan Januari dan Februari 2010 telah terjadi banjir rob di sebagian area Surabaya dengan tingkat penggenangan antara 20 hingga 160 cm dengan rentang waktu 30 menit hingga 6 jam (Iwa, 2010). Kejadian banjir pun terjadi di Mei 2013 dengan ketinggian banjir 50-100 cm dan menggenangi 400 rumah di Kelurahan Morokrembangan dan ketinggian 50 cm di Jalan Kalianak (RRI, 2013).

Gambar 1. Peta Prediksi Genangan *Sea Level Rise* di Kawasan Pantai Utara Surabaya
Sumber : Ariquint, 2013

Legend

Batas Kab.
Batas Kec.

Point Survey
Banjir Rob
Tidak Tergenang

Kedalaman Genangan (2009):
1,62 - 2,01 m
1,22 - 1,61 m
0,82 - 1,21 m
0,42 - 0,81 m
0,01 - 0,41 m

Kawasan pesisir utara Surabaya merupakan wilayah yang sebagian besar dimanfaatkan untuk kegiatan industri dan pergudangan, pertanian ladang garam, permukiman, militer dan pelabuhan (RZWP Kota Surabaya, 2011). Sedangkan berdasarkan hasil dari penelitian yang dilakukan oleh Meiviana (2004) memperlihatkan laju kenaikan air laut di pesisir Kota Surabaya setinggi 5,47 mm per tahun dalam periode waktu 64 tahun (1925-1989). Pada bulan Januari dan Februari 2010 telah terjadi banjir rob di sebagian area Surabaya dengan tingkat penggenangan antara 20 hingga 160 cm dengan rentang waktu 30 menit hingga 6 jam (Iwa, 2010). Kejadian banjir pun terjadi di Mei 2013 dengan ketinggian banjir 50-100 cm dan menggenangi 400 rumah di Kelurahan Morokrembangan dan ketinggian 50 cm di Jalan Kalianak (RRI, 2013).

Seiring dengan pertumbuhan yang pesat, Kawasan Pantai Utara Surabaya memiliki kerentanan yang juga semakin besar sehingga secara otomatis meningkatkan potensi resiko terhadap bahaya banjir akibat kenaikan permukaan air laut. Hal ini dapat menimbulkan dampak negatif berupa kerugian secara fisik, sosial, ekonomi dan lingkungan apabila terjadi. Berkaitan dengan hal tersebut diperlukan upaya untuk mengurangi tingkat resiko bencana. Maka penelitian ini difokuskan untuk merumuskan faktor-faktor yang mempengaruhi tingkat kerentanan bencana banjir rob di Kawasan Pantai Utara Surabaya sebagai bagian dalam perumusan adaptasi pengurangan risiko banjir rob.

2. METODOLOGI

Pendekatan yang digunakan dalam penelitian ini adalah pendekatan rasionalisme. Suatu pendekatan yang berpandangan bahwa rasio adalah sumber dari segala kebenaran (Endro, 2010).

Penelitian ini diawali dengan perumusan teori pembatasan lingkup, definisi secara teoritik dan empirik yang berkaitan dengan faktor-faktor kerentanan kawasan rawan banjir rob. Selanjutnya, teori tersebut dirumuskan menjadi sebuah konseptualisasi teoritik yang menghasilkan indikator dan variabel penelitian. Tahap terakhir adalah tahap generalisasi hasil, yang bertujuan menarik kesimpulan yaitu faktor-faktor kerentanan terhadap banjir rob pada wilayah studi berdasarkan hasil analisis terhadap fakta empiri dan landasan teori terkait.

Analisa yang digunakan dalam penelitian kali ini adalah analisa content. Teknik ini dilakukkan dengan membandingkan antara variabel dengan teori atau kondisi eksisting sehingga didapatkan faktor yang

berpengaruh terhadap bencana banjir rob (Miles & Huberman, 1992). Adapun alur proses content analisa sebagai mana pada Gambar 2. Kondisi eksisting ini digali dengan melakukan wawancara (in-depth interview) kepada enam stakeholder kunci yang mengetahui kondisi eksisting bencana di wilayah studi.

Gambar 2. Tahapan *Content Analysis*
Sumber : Diolah dari Elo & Kyngas, 2008

3. HASIL

Dalam penelitian ini, kerentanan terhadap banjir rob dapat dibedakan menjadi tiga antara lain kerentanan fisik (kepadatan bangunan, kawasan terbangun, jaringan jalan, listrik, telekomunikasi, PDAM, saluran drainase, permukiman di dataran rendah, fasilitas penting dan khusus serta kualitas bangunan), kerentanan sosial (kepadatan dan laju pertumbuhan penduduk, penduduk usia tua dan balita, penduduk wanita, pemahaman masyarakat terhadap bencana, keterlibatan masyarakat dalam manajemen bencana, tingkat nutrisi masyarakat dan kepemilikan teknologi komunikasi), kerentanan ekonomi (presentase penduduk yang bekerja disektor rentan, presentase penduduk miskin dan pendapatan masyarakat), Kerentanan lingkungan (Tutupan hutan lindung/kawasan resapan air, tutupan hutan mangrove, kedekatan dengan sungai, berada di dataran rendah dan berada diatas tanah rawa). Berbagai faktor tersebut didapat dari hasil review pada berbagai literatur meliputi; teori kebencanaan yang meliputi konsep resiko (Kodoatie dan Sjarief, 2010; Vicente dan de Mesa, 2008; Kumpulainen ,2006; Affeltranger, 2006; Bimas Rusty, 2005), kerentanan (vulnerability) (Awotona, 1997; Harta, 2005; Miladan, 2009; Maskrey, 1989; Anderson dan Wodrow, 1989; Maskrey, 1998; Miladan, 2009) dan teori terkait banjir rob (Pugh, 1987; Asmaul, 2008; Martius, 2006).

Dalam menganalisa variabel kerentanan yang berpengaruh, proses content analysis dilakukan sebagaimana pada contoh berikut. **Tahap pertama** adalah menentukan unit analisis dalam memperoleh informasi terkait faktor kerentanan banjir rob. Unit analisis yang digunakan adalah unit kalimat. Dalam menentukan unit kalimat, pemahaman kembali isi transkrip wawancara sangatlah diperlukan (**tahap dua**). Untuk memudahkan, dilakukan pengkodean untuk setiap unit analisis, berikut merupakan contoh unit analisis untuk variabel jaringan jalan.

Kode T1.8 Responden 1

"Yah kalau memang soal aksesibilitas, terutama saat banjir, kadang mereka harus melewati, mau masuk atau keluar menggunakan perahu saat banjir rob datang.."

(Agus Maryono, Kasubid Penanggulangan Bencana)

Kode T4.9 Responden 4

"Ya jelas ganggu mas, semenjak ada rob ya tambah macet, tidak ada rob saja macet"

(Moh. Syafi'i, Wakil Ketua LKMK Morokrembangan)

Dari kedua pernyataan diatas terlihat bahwa jaringan jalan merupakan salah satu variable kerentanan banjir rob. Variable ini dipilih karena jaringan jalan terkenda dampak negatf dari adanya banjir rob. Jalan sering tergenang oleh banjir rob sehingga menyebabkan kemacetan pada beberapa lokasi.

Setelah ditentukan unit analisis beserta pengkodeannya, langkah berikutnya (tahap tiga) adalah mengembangkan matriks analisis. Tabel.1. adalah contoh matrik hasil analisa konten pada setiap stakeholders untuk setiap variabel.

Tabel 1. Contoh Matrik hasil Pengkodean

Kerentanan	Variabel	Kelompok Stakeholders			
		Pemerintah		Masyarakat	
		Sartlak PB	Dinas PU Pematusan dan Bina Marga	LKMK Kelurahan Morokrembangan	Tokoh Masyarakat Kelurahan Greges
Kerentanan Fisik (Lingkungan Buatan)	Kepadatan bangunan	T1.3	T3.1, T3.5	T4.36	
	Kawasan terbangun			T4.3, T4.4, T4.15	T2.3, T2.16, T2.17
	Jaringan jalan	T1.8, T1.26	T3.6	T4.1, T4.6, T4.9	T2.13
	Jaringan listrik	T1.10	T3.7	T4.17, T4.19	T2.10
	Jaringan telekomunikasi	T1.9	T3.9	T4.20	
	Jaringan PDAM	T1.21	T3.8	T4.18	T2.11
	Saluran drainase	T1.12			T2.28

Sumber : Penulis, 2014

Keterangan kode:

Merah : Setuju bahwa variable tersebut termasuk variabel kerentanan banjir rob

Hitam : Tidak Setuju bahwa variable tersebut termasuk variabel kerentanan banjir rob

Dalam matriks ini, setiap pendapat akan dikelompokkan berdasarkan kelompok stakeholders, meliputi governance, civil society dan private sector. Selain itu, pendapat dikategorisasi berdasarkan jenis variabel kerentanan (**tahap empat dan lima)**.

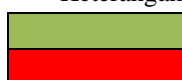
Berdasarkan hasil content analysis, Tabel 2 (matriks analisis) menunjukkan bahwa 13 variabel menurut para responden merupakan variabel yang tidak berpengaruh dan 14 variabel berpengaruh dalam kerentanan bencana banjir rob pada wilayah studi.

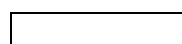
Pada tabel 2, beberapa variabel yang menjadi perdebatan antara lain variabel saluran drainase, fasilitas penting, fasilitas khusus, pendapatan masyarakat, tutupan hutan lindung/kawasan resapan air serta tutupan hutan mangrove. Hal ini terjadi karena beberapa responden beranggapan bahwa variabel tersebut mempengaruhi kerentanan terhadap bencana banjir dan sebagiannya berpikir sebaliknya.

Tabel 2. Tanggapan Responden Terhadap variabel Penentu Bencana Banjir Rob

No	Faktor	No. Responden						Kesimpulan
		1	2	3	4	5	6	
1	Kepadatan bangunan							
2	Kawasan terbangun							
3	Jaringan jalan							
4	Jaringan listrik							
5	Jaringan telekomunikasi							
6	Jaringan PDAM							
7	Saluran drainase							
8	Permukiman di dataran rendah							
9	Fasilitas penting							
9	Fasilitas khusus							
10	Kualitas bangunan							
11	Kepadatan penduduk							
12	Laju pertumbuhan penduduk							
13	Penduduk usia tua							
14	Penduduk usia balita							
15	Penduduk wanita							
16	Pemahaman masyarakat terhadap bencana							
17	Manajemen bencana oleh masyarakat							
18	Tingkat nutrisi masyarakat							
19	Kepemilikan teknologi komunikasi							
20	Persentase penduduk yang bekerja di sektor rentan							
21	Persentase penduduk miskin							
22	Pendapatan masyarakat							
23	Tutupan hutan lindung/ kawasan resapan air							
24	Tutupan hutan mangrove							
25	Kedekatan dengan sungai							
26	Berada di dataran rendah							
27	Berada di atas tanah rawa							

Sumber : Komparasi Transkrip Wawancara dengan Variabel, 2014

Keterangan :

= Berpengaruh

= Tidak Berpengaruh

= Null

Pada tabel tersebut, beberapa variabel yang menjadi perdebatan antara lain variabel saluran drainase, fasilitas penting, fasilitas khusus, pendapatan masyarakat, tutupan hutan lindung/kawasan resapan air serta tutupan hutan mangrove. Hal ini terjadi karena beberapa responden beranggapan bahwa variabel tersebut mempengaruhi kerentanan terhadap bencana banjir dan sebagiannya berpikir sebaliknya.

Berikut akan dijelaskan alasan-alasan yang diambil dalam mempertimbangkan karakteristik dalam variabel-variabel perdebatan tersebut. Pertimbangan ini dijadikan sebagai dasar dalam pengambilan kesimpulan keberpengaruhan variabel tersebut.

Tabel 3. Penjelasan Penentuan Klasifikasi Beberapa Variabel Pengaruh Banjir Rob

Variabel	Berpengaruh		Tidak Berpengaruh	
	Responden	**Pernyataan**	**Responden**	**Pernyataan**
Fasilitas Khusus	• LKMK Kelurahan Morokrembangan • Tokoh Masyarakat di Kelurahan Greges	Berdasarkan pendapat kedua stakeholder tersebut, pada wilayah penelitian terdapat pangkalan militer di Kawasan Pantai Utara Surabaya yaitu Kodim 0830 serta perumahan militer. Mereka berpendapat bahwa karena wilayahnya dekat dengan pesisir, maka pangkalan militer tersebut juga terdamapak oleh banjir rob	• Sartlak Penanggulangan Bencana Kota Surabaya • Dinas PU Binamarga dan Pematusan Kota Surabaya • Kelompok Nelayan di Kelurahan Morokrembangan	Pangkalan militer tidak berdampak apabila terjadi banjir rob. Karena pangkalan militer tersebut dekat dengan Bozem Morokrembangan yang berfungsi mengurangi genangan air di wilayah penelitian.
	Kesimpulan			
	Fasilitas khusus tidak mempengaruhi tingkat kerentanan terhadap banjir rob di wilayah penelitian. Pada kondisi eksisting terdapat fasilitas penting seperti Pelabuhan Tanjung Perak dan Pangkalan Militer Kodim 0830, namun kondisi fasilitas tersebut tidak begitu terdampak dengan adanya fenomena banjir rob yang ada. Hal ini dikarenakan kedua fasilitas tersebut memiliki rumah pompa dan tanggul tersendiri yang dapat meminimalisir terjadinya genangan. Bahkan terdapat stakeholder yang mengatakan apabila fenomena banjir pasang sering dimanfaatkan anggota militer sebagai latihan air.			
Pendapatan Masyarakat	• LKMK Kelurahan Morokrembangan • Tokoh Masyarakat di Kelurahan Greges • Kelompok Nelayan Tambak di Kelurahan Kalianak	Banjir rob mempengaruhi pendapatan masyarakat terutama warung, dikarenakan ketika banjir rob mereka tidak bisa berjualan atau berdagang., Banjir rob yang terjadi sangat mempengaruhi pendapatan nelayan tambak. Hal ini dikarenakan air pasang yang terjadi sudah bercampur dengan limbah sehingga menyebabkan habitat tambak seperti kepiting, rajungan, udang dan bandeng mengalami penurunan. Sebagai contoh produksi udang yang sebelumnya mencapai 5 ton berkurang drastis menjadi 5 kg.	• Sartlak Penanggulangan Bencana Kota Surabaya • Dinas PU Binamarga dan Pematusan Kota Surabaya • Kelompok Nelayan di Kelurahan Morokrembangan	Ketika banjir rob terjadi masyarakat tetap bekerja seperti biasa, karena intensitas banjir yang hanya 2 – 3 jam sehingga tidak mempengaruhi kegiatan. Sedangkan masyarakat yang bekerja sebagai pedagang sudah mengantisipasi dengan tidak berjualan, ketika air surut mereka kembali berjualan.

Variabel	Berpengaruh		Tidak Berpengaruh	
	Responden	**Pernyataan**	**Responden**	**Pernyataan**
	Kesimpulan			
	Pendapatan masyarakat berpengaruh terhadap tingkat kerentanan banjir rob di wilayah penelitian. Namun pendapatan masyarakat yang berpengaruh merupakan pendapatan masyarakat yang bekerja di sektor yang terdampak atau rentan terhadap fenomena banjir rob seperti kegiatan berdagang dan pertambakan. Terkait dengan pertambakan, para nelayan tambak mengalami penurunan produktivitas yang berdampak pada penurunan pendapatan dikarenakan air pasang yang ada tercampur oleh limbah. Terkait dengan perdagangan, ketika banjir rob terjadi mengakibatkan masyarakat tidak dapat berjualan sehingga mempengaruhi tingkat pendapatan			
Tutupan Hutan Lindung/Kawasan Resapan Air	• LKMK Kelurahan Morokrembangan • Tokoh Masyarakat di Kelurahan Greges • Kelompok Nelayan Tambak di Kelurahan Kalianak	Kawasan resapan air di wilayah penelitian sudah banyak yang berkurang. Pada Kelurahan Kalianak dan Greges banyak kawasan pertambakan yang sudah berubah fungsi menjadi pergudangan. Sedangkan di Kelurahan Morokrembangan, hilangnya kawasan resapan air menyebabkan wilayah penelitian sering terjadi genangan.	• Sartlak Penanggulangan Bencana Kota Surabaya • Dinas PU Binamarga dan Pematusan Kota Surabaya	Pada wilayah penelitian keberadaan kawasan resapan air digantikan oleh Bozem Morokrembangan. Sehingga ketika banjir rob terjadi aliran air akan ditampung di dalam bozem sehingga tidak sampai menyebabkan genangan di wilayah penelitian
	Kesimpulan			
	Tutupan hutan lindung / kawasan resapan air mempengaruhi tingkat kerentanan terhadap banjir rob di wilayah penelitian. Berdasarkan kondisi eksisting, wilayah penelitian merupakan kawasan padat dimana sangat sedikit ditemukan daerah resapan air. Keberadaan Bozem Morokrembangan tidak begitu optimal dalam mengurangi genangan banjir rob di wilayah penelitian, dikarenakan wilayah penelitian yang sangat luas sedangkan Bozem Morokrembangan hanya mampu mengkover beberapa kawasan di wilayah penelitian.			

Sumber : Penulis, 2014

Setelah diperoleh variabel yang mempengaruhi tingkat kerentanan banjir rob maka tahap berikutnya adalah mengidentifikasi faktor – faktor yang mempengaruhi tingkat kerentanan bencana banjir rob di Kawasan Pantai Utara Surabaya. Terdapat beberapa variabel yang memiliki kesamaaan karakteristik sehingga dalam penentuan faktor-faktor yang berpengaruh ini akan lebih dispesifikkan untuk menggambarkan kondisi sebenarnya pada wilayah penelitian, berikut merupakan faktor – faktor yang mempengaruhi tingkat kerentanan bencana banjir rob di Kawasan Pantai Utara Surabaya antara lain :

Tabel 5. Faktor - faktor yang Mempengaruhi Tingkat Kerentanan Banjir Rob di Kawasan Pantai Utara Surabaya

Faktor	**Tingkat Kepadatan Penduduk yang Tinggi**
Alasan	Kawasan Pantai Utara Surabaya merupakan kawasan dengan jumlah penduduk yang tinggi. Jumlah penduduk yang bertambah setiap tahunnya menyebabkan **kepadatan penduduk** di wilayah penelitian meningkat. Hal ini juga dipengaruhi oleh **laju pertumbuhan penduduk** yang tinggi sehingga semakin cepat laju pertumbuhan penduduk di suatu wilayah maka semakin rentan penduduk tersebut terhadap banjir rob. Berdasarkan kondisi eksisting di wilayah penelitian didominasi kawasan permukiman padat, hal ini dibuktikan dengan banyaknya permukiman kumuh disana. Banyaknya penduduk yang berasal dari luar wilayah penelitian menambah padatnya penduduk di wilayah penelitian.

Faktor	Berada di Kawasan dengan Topografi Rendah
Alasan	Kawasan Pantai Utara Surabaya merupakan kawasan pesisir yang **berada di dataran rendah** sehingga ketika terjadi banjir rob tidak jarang **permukiman penduduk yang berada di dataran rendah** tersebut tergenang banjir pasang tersebut. Seringnya peninggian yang berkali – kali dilakukan oleh masyarakat mengindikasikan apabila wilayah penelitian memiliki ketinggian yang sama dengan ketinggian air laut. Berdasarkan kondisi eksisting wilayah penelitian memiliki topografi berkisar 0 – 7,28 meter dikategorikan sebagai dataran rendah
Faktor	**Berkurangnya Kawasan Resapan Air dikarenakan Banyaknya Kawasan Terbangun**
Alasan	Kawasan Pantai Utara Surabaya merupakan kawasan padat dimana sangat sedikit ditemukan **kawasan resapan air**. Beberapa kawasan resapan air seperti **kawasan hutan mangrove** dan lahan tambak sudah banyak berkurang dikarenakan banyaknya pembangunan di wilayah penelitian. Kawasan resapan air yang sebelumnya berupa tambak dan mangrove berubah fungsi menjadi **kawasan terbangun** berupa permukiman dan pergudangan. Banyaknya kawasan terbangun ini mengakibatkan kawasan yang dulunya tidak terdampak banjir rob menjadi terdampak akan banjir rob. Hal ini mengindikasikan semakin banyaknya lahan terbangun menyebabkan semakin rentan terhadap dampak banjir rob
Faktor	**Menurunnya Pendapatan Masyarakat pada Sektor Rentan**
Alasan	**Pendapatan masyarakat** yang terpengaruh oleh adanya banjir rob adalah pendapatan masyarakat yang **bekerja di sektor rentan.** Mayoritas penduduk di Kawasan Pantai Utara Surabaya adalah nelayan dan nelayan tambak. Dimana banjir rob yang terjadi menyebabkan habitat ikan di tambak mati dikarenakan air pasang yang masuk ke tambak merupakan air pasang yang terkena limbah rumah tangga dari saluran drainase. Selain itu tren kenaikan air yang terjadi dan faktor angin serta gelombang menyebabkan nelayan kesulitan mencari ikan di laut. Untuk sektor perdagangan, banjir rob yang terjadi menyebabkan pada pedagang tidak bisa berjualan.
Faktor	**Terdampaknya Sarana dan Prasarana Penting**
Alasan	Banjir rob yang terjadi di berdampak pada tergenangnya sarana dan prasarana penting di Kawasan Pantai Utara. Beberapa prasarana seperti **jaringan jalan** sering tergenang oleh banjir rob sehingga menyebabkan kemacetan pada beberapa lokasi. Sedangkan **sarana penting** yang terdampak banjir rob di wilayah penelitian adalah fasilitas pendidikan dan kantor kelurahan sehingga menyebabkan terganggunya aktivitas pelayanan kepada masyarakat. Ketinggian banjir rob yang bervariasi antara 25 – 100 cm menyebabkan genangan pada sarana dan prasarana penting sehingga menganggu aktivitas masyarakat
Faktor	**Buruknya Kondisi Saluran Drainase**
Alasan	Kondisi saluran drainase yang ada di wilayah penelitian kurang berfungsi secara optimal. Dimana terdapat saluran drainase yang tertutup oleh bangunan selain itu juga terdapat drainase yang kondisinya penuh dengan sampah sehingga ketika banjir rob terjadi luasan genangan semakin luas dan intensitas genangan semakin lama karena keberadaan saluran drainase yang tidak mampu mengalirkan air pasang. Kondisi drainase yang penuh dengan sampah juga menyebabkan banjir rob terjadi semakin kotor
Faktor	**Berada di Wilayah yang Dekat Sungai**
Alasan	Kedekatan dengan sungai berpengaruh terhadap tingkat kerentanan banjir rob di wilayah penelitian. Berdasarkan kondisi eksisting, wilayah penelitian merupakan wilayah yang banyak dilalui aliran sungai, dimana terdapat 7 aliran sungai. Ketika banjir rob terjadi, air pasang yang masuk selalu melewati muara sungai lalu berlanjut menggenangi permukiman warga dan jalan raya. Sehingga kawasan yang terdampak oleh banjir rob bukan hanya kawasan yang dekat dengan laut namun juga pesisir
Faktor	**Kawasan Terbangun Berada di Lahan Rawa**
Alasan	Kawasan Pantai Utara Surabaya merupakan kawasan pesisir dimana banyak terdapat kawasan rawa. Semakin tingginya laju pembangunan menyebabkan luasan tanah rawa berkurang digantikan oleh bangunan. Bangunan yang dibangun di atas tanah bekas rawa memiliki pondasi yang kurang kuat sehingga berdasarkan kondisi di lapangan banyak ditemui bangunan yang ambles atau miring di wilayah penelitian. Dengan semakin meningkatnya ketinggian air serta banyaknya fenomena bangunan yang ambles menyebabkan semakin rentan terhadap banjilr rob

Sumber : Penulis, 2014

4. Pembahasan

Berdasarkan hasil analisa terlihat bahwa faktor tingkat kepadatan penduduk mengakibatkan tingkat kerentanan semakin meningkat karena semakin tinggi tingkat kepadatan penduduk semakin besar pula individu yang terkena dampak banjir tersebut. Dampak yang dirasakan setiap individu salah satunya adalah menurunnya pendapatan dibandingkan dengan

hari lain. Hal ini menjadi masalah besar karena mayoritas masyarakat yang terdampak merupakan masyarkat berpendapatan rendah hingga sedang yang memiliki rata-rata pendapatan sebasar Rp150.000 hingga Rp 450.000 yang hanya dapat digunakan untuk memenuhi kebutuhan pokok saja (Prasita dan Kisnarti, 2013).

Selain itu, kondisi pantai utara yang memiliki ketinggian sama dengan ketinggian air laut, dekat dengan sungai dan termasuk dalam topografi rendah yaitu berkisar antara 0 – 7,28 meter (ESDM Provinsi Jawa Timur, 2009) mengakibatkan lokasi tersebut sering tergenangi banjir rob. Pesatnya tingkat pembangunan pada wilayah studi menyebabkan kawasan tersebut kehilangan daerah resapan air yang mengakibatkan kawasan yang dulunya tidak terdampak banjir rob menjadi terdampak akan banjir rob. Hal ini diperkuat dengan fakta bahwa pada tahun 2009 area yang terkena dampak banjir pada wilayah studi sebesar 4341,12 Ha sedangkan pada tahun 2013 meningkat menjadi 4902,60 Ha (Ariquint, 2013; Prasita dan Kisnarti, 2013). Lahan terbangun pada daerah penelitian dahulunya merupakan lahan rawa dan hal ini menyebabkan banyaknya bangunan yang ambles atau miring akibat banjir rob di kawasan tersebut (Aguswari, 2013).

Kondisi sarana dan prasarana terutama saluran drainase juga terkena dampak banjir rob di kawasan ini. SDN Morokrembangan, Pelabuhan Tanjung Perak, Jalan Gresik beserta drainase disekitar (Satria, 2013; Lubis, 2010).

Dengan demikian, penelitian ini menyimpulkan bahwa faktor-faktor kerentanan yang telah ditemukan dalam penelitian kali ini merupakan faktor-faktor yang memang mempengaruhi tingkat kerentanan bencana banjr rob di kawasan Pantai Utara Surabaya.

5. Kesimpulan

Setelah dilakukan proses analisa, dapat disimpulkan bahwa terdapat 14 variabel yang paling mempengaruhi tingkat kerentanan terhadap banjir rob di Kawasan Pantai Utara Surabaya dari 27 variabel hasil studi literatur. Dari keempat belas variabel tersebut, ada delapan faktor penting dalam menilai kerentanan untuk merumuskan adaptasi pengurangan risiko banjir rob di masa depan. Kedelapan faktor tersebut adalah tingkat kepadatan penduduk yang tinggi, kawasan dengan topografi yang rendah, berkurangnya kawasan resapan air, pendapatan masyarakat pada sektor rentan, sarana dan prasarana penting, buruknya kondisi saluran drainase, dekatnya dengan wilayah sungai dan kawasan terbangun berada di lahan rawa.

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16 PERAMALAN PROBABILISTIK UNTUK KETIDAKPASTIAN CURAH HUJAN

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Abstrak – *Indonesia mengalami perubahan iklim yang sangat ekstrim dan tidak menentu beberapa waktu belakangan ini. Iklim yang berubah-ubah saat ini ditandai dengan naiknya suhu permukaan secara signifikan dan berkurangnya curah hujan di daerah tropis. Perubahan iklim ini dapat dikatakan masih cukup stabil bila dibandingkan dengan perubahan iklim di masa mendatang, sehingga mengakibatkan sulitnya untuk melakukan peramalan. Di Indonesia, BMKG yang berperan menangani segala sesuatu yang berhubungan dengan iklim dan cuaca, telah menerapkan beberapa metode peramalan. Namun, metode-metode tersebut masih belum mempertimbangkan unsur ketidakpastian. Kelebihan peramalan menggunakan ensemble adalah dapat menangkap adanya unsur ketidakpastian tersebut. Namun pada ensemble seringkali terjadi underdispersive atau overdispersive, sehingga dibutuhkan suatu proses kalibrasi untuk menghasilkan peramalan yang lebih akurat. Dalam penelitian ini, digunakan metode kalibrasi peramalan ensemble, yaitu penggabungan beberapa metode peramalan, dimana metode ini mampu memprediksi, baik jangka pendek maupun panjang dengan baik dan sangat relevan dengan iklim saat ini yang mengandung unsur-unsur ketidakpastian yang tinggi. Metode kalibrasi peramalan ensemble yang digunakan adalah Bayesian Model Averaging (BMA), yang diaplikasikan pada data curah hujan di Jember. Melalui penelitian ini, diperoleh peramalan probabilistik berupa PDF terkalibrasi untuk data curah hujan dengan panjang training window optimum, yaitu m = 15.*

***Keywords* :** *Bayesian Model Averaging, Curah Hujan, Ensemble, Kalibrasi.*

PENDAHULUAN

Indonesia merupakan suatu negara dengan luasan perairan relatif cukup besar yang memiliki karakteristik berbeda dengan atmosfer di daerah khatulistiwa lainnya, yang dikenal sebagai Indonesia Maritime Continent (IMC). Hal ini disebabkan karena letak geografisnya yang unik, yaitu berada di antara Samudera Hindia dan Pasifik, serta di antara Benua Asia dan Australia. Oleh karena itu, iklim di Indonesia dicirikan oleh keragaman curah hujan yang cukup besar antar daerah.

Prakiraan curah hujan secara terperinci sampai ke wilayah-wilayah masih sangat sedikit. Penelitian tentang prakiraan curah hujan untuk suatu wilayah sangat dibutuhkan untuk menunjang pembangunan di berbagai bidang (Tresnawati, dkk., 2000). Disamping itu, prakiraan curah hujan juga sangat dibutuhkan untuk mengatisipasi bencana banjir, sehingga pengembangan metode prakiraan curah hujan perlu terus ditingkatkan (model dan komputasi).

Telah banyak penelitian yang dilakukan mengenai beberapa metode peramalan *ensemble* dalam dunia meteorologi. Salah satunya, Raftery *et al.* (2005) menyatakan bahwa salah satu karakteristik dari peramalan *ensemble* adalah sering kali bersifat *underdispersive*. Disamping itu, ada pula Sloughter *et al.* (2007) yang menulis tentang peramalan *ensemble* sebagai metode *post-processing* untuk (*precipitation*). Di Indonesia sendiri telah ada beberapa pengembangan penelitian mengenai peramalan *ensemble*, diantaranya adalah Kuswanto (2010) yang mengembangkan metode kalibrasi untuk data *non-normal* menggunakan distribusi *meta-gaussian*. Ada pula Kadarsah (2010) yang menguji kehandalan model HyBMG menggunakan aplikasi ROC.

Saat ini, kondisi iklim menjadi topik hangat, tidak hanya di Indonesia tetapi juga hampir di seluruh dunia karena unsur ketidakpastiannya yang sangat tinggi.

Sudah pernah dibulikasikan di Jurnal Penataan Ruang PWK ITS

Oleh karena itu, dalam penelitian ini dilakukan suatu proses kalibrasi yang bertujuan untuk mereduksi bias terhadap mean sehingga dapat mendekati nilai observasi dan melakukan penyesuaian terhadap nilai varians dari hasil peramalan. Metode kalibrasi yang digunakan dalam penelitian ini adalah metode Bayesian Model Averaging (BMA), yang diaplikasikan pada data curah hujan di Jember. Dengan penggunaan metode ini diharapkan dapat menghasilkan peramalan yang lebih akurat dan reliable, dengan training window yang optimum.

METODOLOGI PENELITIAN

Variabel Penelitian

Variabel penelitian yang digunakan pada penelitian ini adalah variabel curah hujan bulanan, berupa peramalan ensemble yang diperoleh melalui software BMKG yang dinamakan HyBMG, dengan empat model peramalan (ANFIS, ARIMA, Wavelet-ANFIS dan Wavelet-ARIMA). Simulasi dari data tersebut dilakukan sebanyak 24 lead (24 bulan ke depan) untuk bulan Februari 2005 sampai Desember 2009. Namun panjang lead yang akan digunakan adalah lead ke-1, ke-6, ke-12, ke18 dan ke-24. Data time series ini merupakan data curah hujan di Jember (Stasiun Sukowono).

Metode Analysis

***Bayesian Model Averaging* (BMA) dengan *Expectation Maximization* (EM)**

Bayesian Model Averaging (BMA), yang pertama kali dikenalkan oleh Raftery, *et al.* (2005), merupakan salah satu metode statistika yang dapat mengkombinasi model-model statistik sekaligus mengkalibrasi model tersebut pada saat yang sama memberikan hasil yang lebih akurat daripada metode kalibrasi lain. Proses kalibrasi yang dimaksud adalah proses untuk mereduksi nilai bias *mean* dengan nilai varians yang sesuai. Ide dasar dari BMA ini adalah mendapatkan posterior distribusi berdasarkan bobot yang sesuai pada masing-masing *probability* posteriornya, dimana bobot tersebut diberikan berdasarkan kemampuan peramalan dari masing-masing model *ensemble* (Vrugt, *et. al*., 2008)

Model BMA untuk peramalan *ensemble* dinamis dapat dinyatakan sebagai *mixture function* seperti pada persamaan (1) berikut ini:

$$p(y|f_1,\ldots,f_k)=\sum_{k=1}^{K} w_k g_k(y|f_k) \quad (1)$$

dimana w_k merupakan peluang *posterior* dari ramalan ke-*k* yang menjadi ramalan terbaik dan bernilai non negatif, yang apabila dijumlahkan maka akan sama dengan satu Metode BMA yang telah dijelaskan mengasumsikan bahwa PDF bersyarat $g_k(y \mid f_k)$ dari anggota *ensemble* yang berbeda ini diperkirakan memiliki distribusi tertentu, sesuai dengan variabel yang digunakan. Salah satunya adalah distibusi Normal yang terpusat pada fungsi linier dari persamaan *ensemble* sebelum terkalibrasi dengan

$$y|f_k \sim N(a_k + b_k f_k, \sigma^2) \quad (2)$$

dimana a_k dan b_k merupakan koreksi bias yang diperoleh dari regresi linier sederhana antara *y* dan f_k, untuk setiap peramalan *ensemble*. Terdapat dua metode dalam menaksir parameter bobot dan varians, yaitu pendekatan *Markov Chain Monte Carlo* (MCMC) dan *Expectation Maximization* (EM). Namun penelitian kali ini akan menggunakan metode BMA dengan pendekatan EM.

Algoritma EM merupakan suatu prosedur iteratif dari estimasi maksimum likelihood. Pertama kali perlu ditentukan nilai awal dari bobot dan varians untuk kemudian algoritma EM akan berjalan secara iteratif antara *expectation* dan *maximization* sampai diperoleh kondisi yang konvergen. Pada step *expectation*, nilai h_{kt} diestimasi kembali dengan diberikan nilai bobot dan varian terbaru mengikuti persamaan (5) berikut ini:

$$\hat{h}_{kt}^{(j)}=\frac{w_k g(y_t|f_{kt},\sigma^{(j-1)})}{\sum_{l=1}^{k} w_l g(y_t|f_{lt},\sigma^{(j-1)})} \quad (3)$$

Dimana j merupakan jumlah iterasi dan $g(y_t|f_{kt},\sigma^{(j-1)})$ adalah PDF bersyarat dari anggota *k* yang berpusat pada y_t. Pada step *maximization*, nilai dari bobot dan varian diperbarui menggunakan nilai estimasi dari h_{kt} yaitu $\hat{h}_{kt}^{(j)}$ seperti pada persamaan (6) dan (7) berikut:

$$w_k^{(j)}=\frac{1}{n}\sum_t^n \hat{h}_{kt}^{(j)} \quad (4)$$

$$\sigma^{2(j)}=\frac{1}{n}\sum_t^n \sum_{k=1}^{K} \hat{h}_{kt}^{(j)}(y_t-f_t)^2 \quad (5)$$

Dengan iterasi antara *expectation* dan *maximization*, algoritma EM memperbarui nilai w_k dan σ^2. Iterasi berhenti sampai nilainya konvergen dengan toleransi yang sangat kecil (Vrugt, *et al.*, 2008)

Curah Hujan

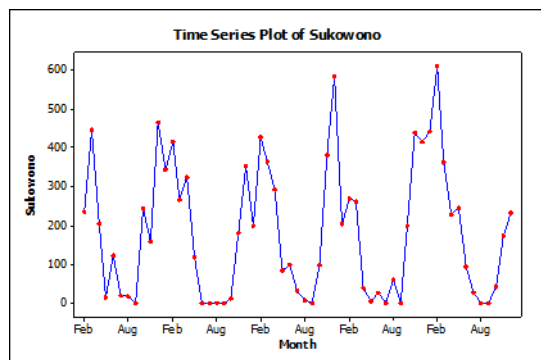
Hujan merupakan satu bentuk precipitation yang berwujud cairan. Berdasarkan definisi BMKG, jenis-jenis hujan berdasarkan curah hujannya dibagi menjadi tiga, yaitu hujan sedang (20-50 mm/hari), hujan lebat (50-100 mm/hari), dan hujan sangat lebat (lebih dari 100 mm/hari).

Secara astronomis, sebagian besar wilayah Indonesia berada di sekitar khatulistiwa dan memiliki curah hujan yang cukup besar terutama di Indonesia bagian barat, dengan rata curah hujannya 2.000–3.000 mm/tahun dan semakin ke arah timur curah hujannya semakin kecil kecuali Maluku dan Papua. Daerah

persebaran hujan di Indonesia dapat dilihat pada Gambar 1 berikut:

Gambar 1. Daerah Persebaran Hujan di Indonesia

HASIL DAN PEMBAHASAN

Data yang digunakan dalam penelitian ini adalah data peramalan ensemble curah hujan bulanan di Jember, yaitu di stasiun Sukowono mulai Februari 2005 sampai Desember 2009, yang diperoleh dari BMKG dengan menggunakan suatu software tertentu yaitu HyBMG (Hybrid BMG).

Gambar 2. Plot *Time Series* Data Curah Hujan di Stasiun Sukowono Jember

Dari Gambar 2 diatas dapat dilihat bahwa rata-rata bulanan curah hujan di stasiun Sukowono adalah sekitar 166 mm. Curah hujan tertinggi yang tercatat di stasiun Sukowono adalah 524 mm yang terjadi pada bulan Maret 2008. Sedangkan pertengahan tahun tercatat sebagai curah hujan terendah di Jember. Secara umum, curah hujan di Jember berdasarkan pencatatan di stasiun Sukowono tersebut memiliki curah hujan sedang, dimana pada bulan-bulan tertentu, yaitu awal dan akhir tahun, curah hujannya terbilang tinggi diantara bulan-bulan yang lain.

Peramalan *Ensemble*

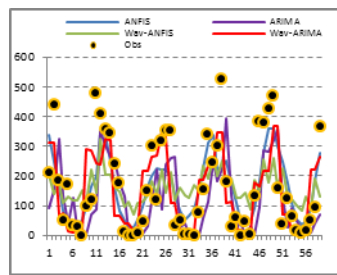
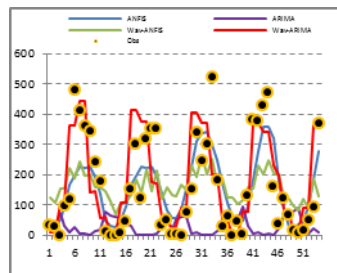
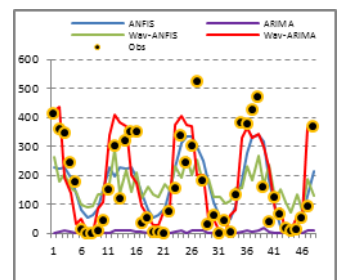
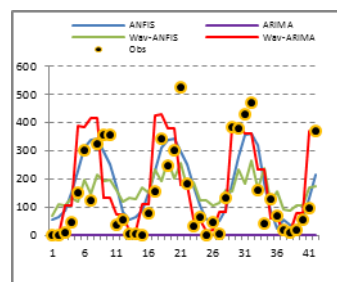
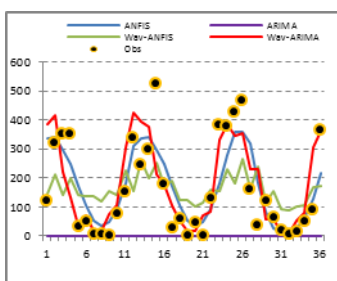
Peramalan *ensemble* dilakukan menggunakan suatu *software* khusus yang digunakan BMKG, yaitu HyBMG. Peramalan curah hujan yang dilakukan oleh BMKG tersebut didasarkan pada empat model peramalan yang berbeda, yaitu ANFIS, ARIMA, Wavelet-ANFIS dan Wavelet-ARIMA. Peramalan ini didasarkan pada kebutuhan BMKG untuk peramalan kondisi iklim tertentu. Selain itu, penggunaan lima *lead time* bertujuan mengevaluasi apakah peramalan jangka panjang masih dapat memberikan *performance* yang cukup bagus atau tidak.

Dalam kalibrasi menggunakan metode *Bayesian Model Averaging* (BMA), distribusi dari data merupakan komponen penting untuk menghasilkan peramalan yang reliabel. Menurut Sloughter (2007), curah hujan menyebar mengikuti distribusi Gamma, dimana nilainya adalah *non-negative*. Sementara itu, Scheuerer (2013) menjelaskan bahwa menemukan model probabilitas yang sesuai untuk curah hujan merupakan tantangan tersendiri dibanding variabel iklim yang lain. Beberapa penelitian menyarankan untuk melakukan transformasi tertentu agar sesuai dengan asumsi tersebut. Namun transformasi akan dapat mengubah skala aslinya sehingga terjadi kesalahan informasi. Untuk menghindari hal tersebut, dapat digunakan keluarga distribusi pada data tanpa transformasi. Oleh karena itu, perlu dilakukan pengujian distribusi peramalan *ensemble* untuk mengetahui pola sebaran curah hujan. Tabel 1 berikut ini menyajikan urutan 5 teratas distribusi yang sesuai untuk data curah hujan di Sukowono menggunakan *Easy Fit* berdasarkan uji *Anderson Darling*.

Tabel 1. Urutan Distribusi Menggunakan *Easy Fit*

Urutan	Distribusi
1	Gen. Pareto
2	Gen. Extreme Value
3	Gumbel Max
4	Error
5	**Normal**

Berdasarkan hasil pengujian distribusi diatas dapat dilihat bahwa curah hujan di stasiun Sukowono cenderung menyebar mengikuti distribusi Normal. Hal ini menunjukkan bahwa curah hujan di Indonesia, khususnya Jember memiliki pola penyebaran yang berbeda dengan pola penyebaran curah hujan menurut Sloughter (2007).

Karakteristik Peramalan *Ensemble* di Stasiun Sukowono

Lead ke-1

Lead ke-6

Lead ke-12

Lead ke-18

Lead ke-24

Gambar 3. Plot *Time Series* Peramalan *Ensemble* di Stasiun Sukowono

Dari Gambar 3 diatas dapat dilihat bahwa ANFIS dan Wavelet-ARIMA memberikan *performance* yang baik diantara yang lain. Akan tetapi, ANFIS cenderung memberikan hasil peramalan yang lebih baik karena mendekati nilai observasi. Sedangkan peramalan Wavelet-ANFIS dapat dikatakan cukup baik karena semakin panjang *lead*, *performance* yang diberikan masih cukup konsisten. Untuk ARIMA, semakin panjang *lead*, *performance* yang ditunjukkan semakin jauh dari kisaran nilai observasi, sehingga dapat dikatakan ARIMA merupakan metode yang baik untuk *short lead forecast*. Hal ini menunjukkan bahwa secara umum, ANFIS memberikan *performance* terbaik bahkan untuk peramalan jangka panjang.

Selanjutnya, untuk melihat sifat hasil peramalan *ensemble* dari keempat model peramalan, Tabel 2 berikut ini menyajikan rata-rata (μ) dan standard deviasi (σ) pada data setiap *lead*

Tabel 2. Rata-rata dan Standard Deviasi dari Hasil Peramalan *Ensemble* Curah Hujan di Stasiun Sukowono

Lead	Bulan	Obs	μ	σ
1	*Feb*-05	209	237.05	112.529
	Mar-05	441	213.6	81.413
	⋮	⋮	⋮	⋮
	Des-09	368	185.325	101.775
6	*Jul*-05	33	446.75	53.858
	Aug-05	28	44.3	42.661
	⋮	⋮	⋮	⋮
	Des-09	368	195.775	155.977
12	*Jan*-06	411	228.375	172.476
	Feb-06	359	211.25	177.977
	⋮	⋮	⋮	⋮
	Des-09	368	180.275	147.931
18	*Jul*-06	0	32.225	35.946
	Aug-06	0	44.8	53.316
	⋮	⋮	⋮	⋮
	Des-09	368	188.875	151.081
24	*Jan*-07	121	217.85	178.447
	Feb-07	320	243.025	182.084
	⋮	⋮	⋮	⋮
	Des-09	368	188.075	189.824

Berdasarkan Tabel 2 diatas, dapat diketahui bahwa besarnya nilai *mean* yang lebih besar dari simpangan mengindikasikan bahwa hasil peramalan curah hujan bulanan di stasiun Sukowono masih bersifat *underdispersive*. Hal ini menyebabkan bahwa peramalan *ensemble* tersebut masih belum optimal.

Kalibrasi Peramalan dengan *Bayesian Model Averaging* (BMA)

Sebelumnya telah ditunjukkan bahwa hasil peramalan *ensemble* di stasiun Sukowono masih bersifat *underdispersive*. Oleh karena itu, diperlukan suatu metode *postprocessing* statistik untuk mengkalibrasi hasil peramalan agar diperoleh peramalan dengan reliabilitas yang tinggi.

Metode BMA mengasumsikan bahwa PDF bersyarat $g_k(y|f_k)$ dari hasil peramalan *ensemble*

dari variabel curah hujan dapat didekati dengan distribusi normal. Untuk mengestimasi nilai bobot dan varians ini dilakukan dengan pendekatan algoritma *Expectation-Maximization* (EM). Algoritma EM ini akan berjalan secara iteratif antara *expectation* dan *maximization*, memperbarui nilai w_k dan σ^2, dan akan berhenti ketika

$$l(w_1,\ldots,w_k,\sigma_1^2,\ldots,\sigma_k^2 \mid f_1,\ldots,f_k,y)=\sum_t^m \log\left(\sum_{k=1}^K w_k g_k(y \mid f_k)\right)$$

telah konvergen sehingga diperoleh nilai σ_k dan w_k. Tahapan proses kalibrasi dilanjutkan dengan mendapatkan model BMA seperti pada persaman (1).

Sebagai ilustrasi, Tabel 3 menyajikan nilai bobot, mean dan varians untuk peramalan bulan Desember 2009 untuk lead ke-1 di stasiun Sukowono.

Tabel 3. Parameter Distribusi untuk Desember 2009 (*Lead* ke-1) Menggunakan Metode BMA-EM di Stasiun Sukowono

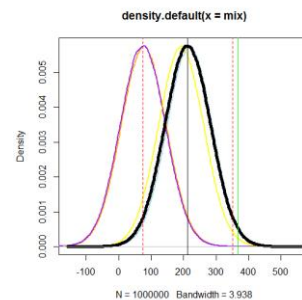
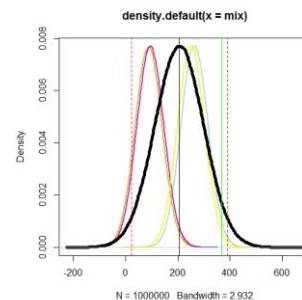
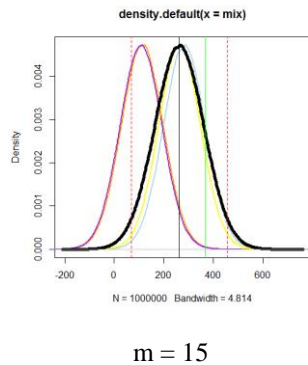
***Training Window* (*m*)**	**Model**	**Parameter**				
		a	***b***	***w***	μ - terkalibrasi	σ - terkalibrasi
10	ANFIS	-51.73	0.98	0.76	212.78	70.33
	ARIMA	22.12	0.79	0		
	Wav-ANFIS	-138.13	1.63	0		
	Wav-ARIMA	9.9	0.69	0.24		
12	ANFIS	-70.98	1.21	0.5	205.6	93.67
	ARIMA	17.48	1.02	0		
	Wav-ANFIS	160.86	1.97	0.34		
	Wav-ARIMA	25.74	0.85	0.16		
15	ANFIS	-42.7	1.17	0.73	262.68	99.21
	ARIMA	46.32	0.96	0		
	Wav-ANFIS	-139.82	1.91	0.1		
	Wav-ARIMA	30.83	0.88	0.17		

Dari Tabel 3 diatas dapat dilihat nilai parameter dan besarnya bobot dari masing-masing model peramalan ensemble. Pada data lead ke-1 untuk semua training window di stasiun Sukowono ini, ANFIS mempunyai bobot secara berturut-turut sebesar 0.76, 0.5, dan 0.73 yaitu angka yang cenderung mendekati nilai 1 (satu). Bobot yang terbesar ini menunjukkan bahwa ANFIS memberikan kontribusi terbesar dalam memprediksi PDF yang terkalibrasi. Sedangkan ketiga model yang lain bernilai mendekati 0 (nol), menunjukkan bahwa Wavelet-ANFIS dan Wavelet-ARIMA memberikan kontribusi yang tidak terlalu besar dalam pembentukan PDF terkalibrasi. Sedangkan ARIMA dapat dikatakan hampir tidak mempunyai kontribusi yang berarti terhadap peramalan PDF terkalibrasi.

Berikut ini adalah ilustrasi PDF terkalibrasi pada lead ke-1, di stasiun Sukowono (Gambar 4) untuk peramalan bulan Desember 2009 dengan panjang training window yang berbeda, yaitu 10, 12, dan 15.

m = 10

m = 12

m = 15

Gambar 4. *Probability Density Function* (PDF) Peramalan *Ensemble Terkalibrasi untuk Desember 2009 Lead ke-1 di Stasiun Sukowono*

Berdasarkan hasil PDF pada Gambar 4 di atas, nilai observasi dapat ditangkap dengan baik oleh taksiran interval, kecuali pada training window 10, dimana interval yang dihasilkan yaitu antara 79.9 dan 345.673 terlalu lebar sehingga nilai observasi, yaitu 368 (garis vertikal berwarna hijau) terletak diluar interval dan jauh dari nilai mean distribusi, yaitu 212.786. Sedangkan kedua training window yang lain telah menunjukkan hasil yang baik karena nilai observasi dapat ditangkap oleh taksiran interval. Taksiran interval untuk m = 12 dan m = 15 secara berturut-turut adalah antara 22.013 dan 389.191 dan antara 68.225 dan 457.128. Namun, panjang training window yang menunjukkan hasil optimum adalah m = 15. Hal ini ditunjukkan oleh nilai mean distribusi pada PDF yang paling mendekati nilai observasi. Sementara itu, berdasarkan bobot yang ada pada Tabel 4, ANFIS mempunyai kontribusi yang besar sehingga PDF yang dihasilkan (berwarna biru) mendekati PDF peramalan ensemble terkalibrasi.

KESIMPULAN

Berdasarkan hasil analisis dan pembahasan, diperoleh kesimpulan bahwa:

1. Model peramalan *ensemble* memiliki bobot yang berbeda dalam pembentukan model kalibrasi peramalan probabilistik menggunakan metode BMA-EM. Model ANFIS dan Wavelet-ARIMA memberikan kontribusi yang cukup besar dalam memperoleh peramalan *ensemble* curah hujan terkalibrasi.
2. Panjang *training window* optimum adalah *m* = 15, karena nilai *mean* terkalibrasi paling mendekati nilai observasi.

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17

ASESMEN BANJIR PROVINSI GORONTALO

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Abstrak – *Bencana banjir di Propinsi Gorontalo telah menyebabkan kerugian pada terganggunya tranportasi, tanaman rusak dan gagal panen, hilangnya jiwa dan harta benda penduduk, menurunnya kesehatan lingkungan dan timbulnya penyakit serta mengganggu aktivitas ekonomi, bisnis dan perkantoran. Kegiatan asesmen banjir di Proponsi Gorontalo diperoleh bahwa banjir disebabkan oleh curah hujan cukup tinggi, kerusakan daerah aliran sungai, sistem drainase belum berfungsi dengan baik, kemiringan lahan terjal daerah aliran sungai di bagian hulu dan landai di bagian hilir, perubahan tata guna lahan yang meningkatkan aliran permukaan dan penurunan area tampungan air, kurangnya penegakan hukum, serta belum optimalnya fungsi dari bangunan sungai dan drainase. Permasalahan banjir yang terjadi di Provinsi Gorontalo sebaiknya diselesaikan dengan pendekatan pengelolaan banjir secara terintegrasi dengan meningkatkan fungsi dari DAS secara keseluruhan mulai dari hulu sampai hilir.*

***Keywords* :** *Pengelolaan, banjir, terintegrasi, curah hujan, Gorontalo.*

1. PENDAHULUAN

Provinsi Gorontalo dari segi geografis terletak pada 00º30’04” – 01º02’30” Lintang Utara dan 112º08’04” – 123º32’09” Bujur Timur, yang berbatasan dengan Provinsi Sulawesi Utara di sebelah timur, Provinsi Sulawesi Tengah di sebelah barat, laut sulawesi di sebelah utara dan Teluk Tomini di sebelah selatan. Luas wilayah Provinsi Gorontalo 12.215,44 km2 yang terdiri atas hutan, rawa, sungai, danau, genangan air, pantai dan tanah lainnya.

Permasalahan banjir sering terjadi pada beberaa tahun terakhir di Provinsi Gorontalo. Kota-kota maupun desa yang berada di dekat sungai sering mengalami genangan akibat air sungai meluap maupun curah hujan yang tidak bisa mengalir ke sungai. Banjir telah merusak prasarana kota dan lingkungan serta permukiman penduduk, yang membawa kerugian pada jiwa dan harta benda yang tidak sedikit.

Tujuan asesmen banjir di Propinsi Gorontalo adalah untuk mengetahui kondisi hidrologi, sistem drainase dan morfologi sungai-sungai rawan banjir, memperoleh gambaran banjir-banjir yang terjadi dan penyebab-penyebabnya serta kerugian yang diakibatkannya dan mendapatkan konsep pengelolaan banjir yang dapat meminimalkan kerugian yang diakibatkannya.

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2. METODOLOGI

- **Lokasi Kegiatan**

Penelitian ini dilakukan pada sungai-sungai di wilayah Provinsi Gorontalo. Sungai-sungai tersebut dikelompokkan dan Wilayah Sungai (WS) dimana provinsi Gorontalo terdiri dari 3 (tiga) WS yaitu WS Limboto-Bolango-Bone, WS Paguyaman dan WS Randangan.

- **Bahan dan Peralatan**

Bahan yang digunakan dalam penelitian ini adalah peta topografi, peta tata guna lahan dan peta tanah, data hujan, data, dan hasil studi-studi banjir terdahulu. Sedangkan peralatan yang digunakan adalah komputer, printer, scanner, GPS, kamera digital dan software aplikasi.

- **Tahapan Penelitian**

Penelitian diawali dengan studi pustaka hasil penelitian terdahulu. Tahap selanjutnya adalah melakukan survey identifikasi dan penggalian informasi kejadian banjir, penyebab kejadian banjir dan dampak yang ditimbulkannya, identifikasi kondisi morfologi sungai dan daerah aliran sungai. Pengumpulan data sekunder dilakukan pengumpulan data sekunder guna menunjang analisa terdiri dari peta-peta, data hidrologi, rencana tata ruang wilayah, rencana pengeloaan sumber daya air dan peraturan/perundangan berkaitan dengan sumber daya air, kuisioner kepada masyarakat dan stage holder. Data hasil survey dan data sekunder dianalisa untuk mendapatkan kondisi fisik, hidrologi, erosi, kejadian banjir, lokasi, tinggi, lama, luas genangan, penyebab banjir dan dampak yang ditimbukannya. Konsep pengelolaan banjir disusun dan diusulkan untuk memecahkan permasalahan banjir di Provinsi Gorontalo.

- **Analisa Data**

- **Kondisi fisik Daerah Aliran Sungai**

Kondisi fisik daerah aliran sungai yang mempengaruhi terjadinya banjir adalah kondisi topografi, kondisi morfologi, dan tata guna lahan.

- **Kondisi Hidrologi**

Koefisien Regim Sungai diperoleh dari hasil perbandingan antara debit maksimum dan debit minimum harian suatu DAS atau Sub-Das.

$$KRS = \frac{Q_{maks}}{Q_{min}} \quad (1)$$

Sungai dikatakan baik bila memiliki KRS < 20, sebaliknya dikategorigan buruk bila KRS>50. Sungai yang memiliki KRS diatara 20 dan 50 dapat dikaterogikan dalam kondisi sedang.

- **Tingkat Erosi**

Dari sekian banyak rumusan yang dapat dipergunakan untuk memprediksi besarnya erosi, model yang dikembangkan oleh Wischmeier dan Smith (1978) — yang biasa dikenal dengan *the Universal Soil Loss Equation* (*USLE*) — dianggap merupakan metode yang paling populer dan banyak digunakan untuk memprediksi besarnya erosi. Persamaan USLE adalah sebagai berikut :

$$\mathbf{A = R.K.L.S.C.P} \quad (2)$$

dimana A adalah banyaknya tanah yang tererosi dalam (ton/Ha/tahun), R adalah faktor curah hujan dan aliran permukaaan (erosivitas hujan), K adalah faktor erodibilitas tanah, L adalah faktor panjang lereng, S adalah faktor kecuraman lereng dan C adalah faktor vegetasi penutup tanah dan pengelolaan tanaman, dan P adalah faktor tindakan-tindakan khusus konservasi tanah. Kelas bahaya erosi sangat ringan bila tanah yang tererosi kurang dari 15 ton/Ha/tahun, ringan bila tanah yang le hilang antara 15-60 ton/Ha/tahun, sedang bila tanah yang hilang antara 60-180 ton/Ha/tahun, berat bila tanah hilang antara 180-480 ton/Ha/tahun dan sangat berat bila kehilangan tanah lebih besar dari 480 ton/Ha/tahun.

- **Identifikasi penyebab banjir dan dampaknya**

Identifikasi kejadian banjir, lokasi, luas, tinggi dan lama genangan serta dampak yang ditimbulkanya diperoleh dengan melakukan survei lapangan, menggali informasi dari masyarakat dan menggali data-data dan informasi dari berbagai literature dan studi-studi terdahulu.

3. HASIL

- **Topografi**

Permukaan tanah di Kabupaten Gorontalo sebagian besar adalah perbukitan dan bergunung-gunung, secara topografi Kabupaten Gorontalo mempunyai kondisi yang variatif yang terdiri dari wilayah datar, kaki bukit, dan pengunungan dengan kemiringan. Luas permukaan wilayah Provinsi Gorontalo hanya 7.5% berada kurang dari 50 m diatas permukaan laut (dpl), 21.26% berada pada ketinggian antara 50-100 m dpl, 51.08% berada pada ketinggian berada pada ketinggian 100-500 m dpl, 15.68% berada pada ketinggian 500-1000m dpl dan 4.49% berada pada ketinggian lebih dari 1000 m dpl (BPS Provinsi Gorontalo 2012). Dengan ketinggian tersebut, luas lahan yang memiliki kemiringan lahan 0-2% adalah 20.12%, 8.08% lahan memiliki kemiringan 2-15%, 34.34% lahan memiliki kemiringan 15-40% dan sisanya 37.39% memiliki kemiringan lebih dari 40% (BPS Provinsi Gorontalo, 2012).

Dengan lebih dari 70% luas lahan di Provinsi Gorontalo dengan kemiringan lahan lebih dari 15%, aliran air hujan diatas permukaan lahan memiliki kecepatan tinggi. Aliran ini menyebabkan debit banjir yang mengalir ke sungai dengan cepat dan potensi erosi lahan besar. Material tanah, tumbuhan, potongan kayu dapat terbawa aliran ke dalam sungai dan dapat menimbulkan pendangkalan atau bahkan penyumbatan penampang sungai. Kondisi ini menyebabkan potensi terjadinya banjir bandang sangat besar.

- **Tata Guna Lahan**

Pengembangan lahan sebagai lahan pertanian didominasi oleh ladang, tegalan, padi sawah, perkebunan dan hutan negara. Penggunaan lahan terbesar di Provinsi Gorontalo adalah 77.65% hutan, kemudian diikuti oleh 5.63% belukar, 5.62% kebun, 2.65% ladang, 2.23% sawah, 1.26% permukiman, 0.4% badan air dan 4.56% tidak teridentifikasi.

Namun demikian luas lahan hutan semakin lama semakin berkurang karena perubahan lahan menjadi area terbangun, ladang, kebun, kawasan industri dan pertambangan serta penggunaan lahan lainnya. Dengan perubahan lahan hutan menjadi lahan lainnya berakibat pada penurunan tingkat resapan air hujan ke dalam tanah sehingga aliran permukaan menjadi meningkat. Peningkatan aliran permukaan berakibat pada peningkatan potensi terjadinya banjir.

- **Kondisi Hidrologi**

Kabupaten Gorontalo beriklim tropis dengan curah hujan tahunan berkisar 1050 – 2500 mm. Suhu udara di Kabupaten Gorontalo rata-rata pada siang hari berkisar antara 30,9oC sampai 33,4oC dengan rata-rata temperatur udara malam hari berkisar antara 26,7oC-29,3oC, suhu tertinggi (32,9 ºC) terjadi pada bulan Mei dan terendah (22, 8 ºC) pada bulan Agustus. dan rata-rata kelembaban udara bervariasi antara 51,5-93,8%, kecepatan angin berkisar antara 1-4 knot.

Sungai Randangan, salah satu sungai yang ada di Provinsi Gorontalo memiliki debit maksimum sebesar 644 m3/det dan debit minimum sebesar 8,94 m3/ det. Perbandingan antara debit maksimum dan minimum diperoleh nilai KRS sebesar 72. Dengan demikian KRS dari Sungai Randangan adalah buruk.

- **Kondisi Morfologi**

Morfologi perbukitan di bagian tengah dari wilayah Provinsi Gorontalo dan dataran yang membentang dari barat ke timur yang ada di bagian utara dan selatan wilayah Provinsi Gorontalo membentuk sungai-sungai yang mengalir ke utara (laut Sulawesi) dan selatan (teluk Tomini). Rangkaian sungai utama beserta anak sungainya membentuk pola penyaluran berbentuk tulang daun (dendritik), dan secara keseluruhan membentuk pola penyaluran sub-paralel. Dengan bentuk ini, sungai-sungai di Provinsi Gorontalo umumnya memiliki panjang sungai pendek, dengan kemiringan terjadi dibagian hulu dan berubah menjadi kemiringan landai di bagian hilir. Debit aliran dari hulu yang mengalir dengan cepat tertahan oleh kemiringan sungai di hilir yang melandai dan pengaruh pasang air laut sehingga air sungai dapat meluap.

- **Tingkat Erosi**

Hasil analisa tingkat erosi dengan metode USLE, diperoleh bahwa besar erosi lahan per tahun di WS Paguyaman adalah 128 Ton/Ha/tahun, WS Limboto-Bone- Bolango adalah 333 Ton/Ha/tahun, dan WS Randangan sebesar 151 Ton/Ha/tahun. Dengan demikian klasifikasi bahaya erosi WS Limboto-Bone-Bolango adalah berat, sedangkan WS Randangan dan WS Paguyaman berada dalam klasifikasi bahaya erosi sedang.

- **Faktor Penyebab banjir dan Dampaknya**

Provinsi Gorontalo terdiri dari 3 (tiga) Wilayah Sungai (WS) yaitu WS Limboto-Bolango-Bone dengan luas 5.253,208 km2, WS Paguyaman dengan luas 2.954,49 km2, dan WS Randangan dengan luas 4.244,3 km2. Hasil identifikasi kejadian banjir, lokasi, penyebab dan dampak yang ditimbulkan dari beberapa studi yang pernah dilakukan disajikan dalam Tabel 1 s/d Tabel 3.

Tabel 1. Hasil identifikasi banjir di WS Randangan

Nama Sungai	Tahun	Lokasi Genangan	Penyebab banjir	Genangan			Sektor yang terdampak
				luas	Lama	Tinggi	
Molosipat Utara	1984	Dusun Molosipat utara	- Intensitas hujan - Topografi rendah	87 Ha	3 hari	1.6 m	- Sawah tergenang - Ternak hilang
	2009		- Kerusakan DAS	50 Ha	3 hari	1.8 m	-Sawah, permukiman & fasilitas umum -Transportasi -Ternak hilang
Milangodaa	Juli 2010	Desa kelapalima, Milangodaa, Londoun, Bunto	- Intensitas hujan - Topografi rendah	500 Ha	1 hari	1.7 m	- Jalan rusak - ternak hilang
	2010		- Kerusakan DAS	300 Ha	1 hari	1.7 m	- Jalan rusak - ternak hilang - korban jiwa 1 org

Babalonge	2009	Desa Babalonge	- Intensitas hujan - Topografi rendah	14 Ha	1 hari	0.5 m	- Permukiman tergenang - Jalan dan jembatan
	2010		- Kerusakan DAS	10 Ha	1 hari	0.4 m	- Permukiman tergenang - Jembatan rusak
Limbula	2009	Desa Limbula	- Intensitas hujan - Topografi rendah	10 ha	1 hari	0.6 m	- Jalan rusak berat -Permukiman tergenang
	2010		- Kerusakan DAS	-	-	0.6 m	-Fasilitas umum tergenang
Randangan	1993	Desa Imbodu, Iloheluma, Manawa, Suka makmur	- Sedimentasi - Pembedungan oleh sampah dan kayu - Pasang surut	-	2-3 hari	0.1-2 m	- Sawah, rumah dan fasilitas umum - Transportasi
	2010	Desa Iloheluma, Manunggal Karya, Ayula, Manawa	- Peningkatan aliran permukaan	-		1 m	- Gagal panen - Ratusan Rumah
Popayato	2009	Desa Kelapa Lima, Milangoda	- Intensitas hujan tinggi - Sungai meluap	-	-	1-1.5 m	- Rumah Tergenang, 4 hanyut & 30 rusak - 1 org meninggal - 8000 warga mengungsi
	2010	Desa Hulawa		230 ha	-	0.5-1 m	- Lahan pertanian - Rumah terendam - Warga mengungsi - Gagal panen

Tabel 2. Hasil identifikasi banjir di WS Limboto-Bolango-Bone

Nama Sungai	Tahun	Lokasi Genangan	Penyebab banjir	Genangan			Sektor yang terdampak
				luas	Lama	Tinggi	
Dulupi	2005	Dusun Huwata Desa Dulupi	- Intensitas hujan - Topografi rendah - Kerusakan DAS	20 Ha	1 hari	0.4 m	- Gagal panen - 100 rumah terendam - Jalan dan drainase - Ternak hilang - aktifitas bisnis & pendidikan
	2009			-	3-4 jam	0.5 m	- irigasi rusak - 100 rumah terendam - Jalan dan drainase - Ternak hilang - aktifitas bisnis & pendidikan
Leboto	2008	Desa leboto	- Intensitas hujan - Topografi rendah - Kerusakan DAS	10 Ha	3 hari	0.5 m	- Ladang terendam - irigasi rusak -Fasilitas umum dan bisnis
	2010	Dusun Tolingo Desa Leboto	- Bangunan sungai rusak	-	4 jam	0.4 m	

Poso	2010	Desa Maluo	- Intensitas hujan - Topografi rendah - Kerusakan DAS - Tanggul rusak	-	4 jam	0.6 m	- Sawah tergenang - Irigasi rusak - Fasiltas umum
Dambalo	2010	Desa Dambalo	- Intensitas hujan - Kerusakan DAS		2 hari	1.5 m	- Sawah tergenang - Permukiman, kantor,sekolah
Persatuan	2009	Desa Persatuan	- Intensitas hujan - Topografi rendah - Kerusakan DAS	50 Ha	2 hari	0.7 m	- permukiman dan sawah -Jembatan rusak -Infrastruktur pendidikan & bisnis -Ternak hilang
	2010	Desa Persatuan		20 Ha	3 jam	0.5 m	-Sawah dan permukiman -Sarana transportasi -Ternak hilang
Padengo	2009	Desa Padengo	- Intensitas hujan - Topografi rendah Kerusakan DAS	10 Ha	2 hari	0.4-0.5 m	- Jalan rusak - Jembatan rusak
Tamalate	2009	Sekitar Sungai Tamalate	- Intensitas hujan tinggi - Kerusakan DAS		1 hari	1-2 m	- Sawah tergenang - Permukiman, perkantoran dan sekolah - Ternak hilang
Molingkapoto	2010	Desa Bauwongbatu	- Intensitas hujan tinggi Kerusakan DAS	-	1 hari	1-2 m	- Sawah tergenang - Permukiman, perkantoran dan sekolah - Ternak hilang
Pontolo	2010	Desa Pontolo	- Intensitas hujan tinggi - Sedimentasi - -Kerusakan DAS	-	2-3 hari	0.3-0.4 m	- Sawah tergenang - Fasilitas umum
Tolongio	2010	Desa Tolongio	- Intensitas hujan tinggi -Kerusakan DAS		1 hari	1-2 m	- Sawah tergenang - Fasilitas umum

Tabel 3. Hasil identifikasi banjir di WS Paguyaman

Nama Sungai	**Tahun**	**Lokasi Genangan**	**Penyebab banjir**	**Genangan**			**Sektor yang terdampak**
				luas	**Lama**	**Tinggi**	
Botumoito	2005	Desa Botumoito, Tutulo, Patoamem	- Intensitas hujan tinggi - Topografi lahan - Kerusakan DAS	-	1 hari	0.6 m	- Rumah 70 KK - Sawah di Desa Patanga - Ekonomi & pendidikan
	2009	Desa Patoameme		3 dsn	1 hari	0.6 m	- Bisnis, perkantoran, & pendidikan - drainase - Transportasi
Dimito	2009	Dusun Abadi 1, Abadi 2 & Tengah	- Intensitas hujan tinggi - Topografi lahan	800 Ha	3 hari	0.7 m	50 rumah, 28 Ha sawah dan 50 Ha pemukiman
	2010		- Kerusakan DAS	200 Ha	-	0.25 m	Sawah dan fasilitas umum

Delihito	2006	Desa Limpato, Paloliangga, Ayuhulalo, Mohunggo, Modolomo, Hungayona	- Intensitas hujan - Topografi rendah - Kerusakan DAS - Backwater akibat Pasang air laut	24 Ha	1 hari	0.6 m	- Sawah - Jaringan Irigasi - 30 Bangunan - 40 Ternak - Jalan terputus
	2009	Desa Limpato		2 Ha	1 hari		- Sawah tergenang - Fasilitas umum tergenang
Rumbia	2009	Desa Rumbia	- Intensitas hujan - Topografi rendah - Kerusakan DAS		1 hari	0.5 m	- Ladang tergenang -Irigasi rusak -Fasilitas umum dan perdagangan tergenang
	2010	3 Dusun di Desa Rumbia	- Penambangan pasir	10 Ha	1 hari	0.4 m	- Sawah terendam - irigasi rusak berat - Fasilitas umum dan perdagangan
Potanga	2007	Desa Potanga	- Intensitas hujan - Topografi rendah - Kerusakan DAS	150 rumah	3-4 hari	0.7 m	- Sawah, permukiman dan fasilitas umum - Ternak hilang
	2009	3 Dusun di Desa Potanga	- Backwater akibat Pasang air laut	100 rumah	1 hari	0.6 m	- Ladang, permukiman - Aktifitas ekonomi
Tilamuta	2004	Kota Tilamuta	- Kapasitas alir sungai tidak mencukupi - Sedimentasi - Perubahan tataguna lahan	-	2 hari	1.25 m	- Transportasi terganggu - Prasarana umum - Ternak hilang

4. PEMBAHASAN

Analisa data menghasilkan kondisi fisik dan hidrologi daerah aliran sungai-sungai di Kabupaten Gorontalo berpegaruh pada banjir. Identifikasi banjir menghasilkan sungai-sungai yang ada di 3 WS Limboto-Bone-Bolango, Paguyaman dan Randangan terjadi banjir yang cukup sering dan menimbulkan dampak kerugian harta benda maupun nyawa manusia.

Permasalahan banjir yang terjadi di Provinsi Gorontalo tidak dapat diselesaikan dengan hanya pendekatan struktural saja seperti pembangunan waduk, sudetan, tanggul dan bangunan pengontrol banjir lainnya. Pendekatan baru tentang pengelolaan banjir harus mempertimbangkan (World Meteorology Organization, 2004) beberapa hal berikut yaitu daerah aliran sungai bersifat dinamik menurut ruang dan waktu. Ada interaksi antara air, tanah/sedimen dan polutan/nutrisi. Peningkatan populasi dan aktivitas ekonomi memberi tekanan pada alam. Peningkatan aktivitas ekonomi di daerah dataran banjir akan meningkatkan kerentanan terjadi banjir. Perubahan tata guna lahan akan menyebabkan peningkatan pada aliran permukaan dan kemungkinan terjadinya banjir. Perubahan intensitas dan durasi hujan sebagai akibat perubahan iklim akan meningkatkan terjadinya banjir banjdang dan banjir musiman. Perlu adanya pertimbangkan bahwa adanya kemungkinan bangunan proteksi banjir yang ada gagal dan bagaimana mengelola situasi tersebut. Pendekatan sebaiknya terintegrasi dengan meningkatkan fungsi dari DAS secara keseluruhan mulai dari hulu sampai hilir serta memadukan dan saling melengkapi antara pengendalian struktur dan non struktur.

5. KESIMPULAN

- Penyebab terjadinya banjir di Provinsi gorontalo adalah curah hujan tinggi, sistem drainase belum berfungsi dengan baik, kondisi topografi, menurunnya kemampuan alir sungai, perubahan tata guna lahan di hulu, kekurangtegasan implementasi hukum bagi pelanggar ketertiban dan kesehatan lingkungan.
- Bencana banjir telah menyebabkan kerugian antara lain terganggunya tranportasi, tanaman rusak dan gagal panen, harta benda penduduk, menurunnya kesehatan lingkungan dan timbulnya

penyakit, terganggunya aktivitas ekonomi, bisnis dan perkantoran.

- Beberapa kegiatan penanggulangan banjir telah dilakukan namun permasalahan banjir masih saja terjadi. Permasalahan banjir yang terjadi di Propinsi Gorontalo sangat komplek, untuk menyelesaikannya perlu dilakukan pengelolaan banjir secara terintegrasi dengan meningkatkan fungsi dari DAS secara keseluruhan mulai dari hulu sampai hilir.

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18 FACTORS FOR ENHANCING COMMUNITY RESILIENCE TO FLOOD IN CENTINI VILLAGE

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Abstrak – *Resilience is an emerging term in disaster risk management. It focuses on how community can 'bounce back' after a disaster event. To define the ability of a community to bounce back, I discuss resilience as a gap of vulnerability levels in two time frames (current and future) after applying certain adaptations. Consequently, the level of community resilience will depend on vulnerability levels and the adaptations in a community. This understanding becomes a key concern in this paper as well as the first step of a successful disaster risk management. To select key vulnerability factors, literature in the arena of disaster, flood, climate change and vulnerability are reviewed. The reviewing results are then verified to the 18 stakeholders by two rounds of Delphi questionnaires. From the literature, 29 potential vulnerability factors are concluded. The two round Delphi questionnaires have verified that the 25 out of 29 are relevant vulnerability factors. Moreover, the stakeholders also suggested 6 new factors as relevant factors. Therefore, the final vulnerability factors are 31 for this case study. After reviewing the output of semi-structured interviews in Delphi questionnaires, 11 current adaptations based on final vulnerability factors are concluded. 8 out of 11 current adaptations are more likely to sit in reactive actions rather than proactive ones. Consequently, more proactive actions are needed to enhance community resilience in the future time. By considering the final factors and supporting literature, 11 proactive adaptations are proposed. Those proactive adaptations are grouped into 3 main classifications of adaptation, that are; spatial plan, economic development program and proactive community actions. As a result, in enhancing community resilience to flood in Centini Village, I propose the public decision makers to understand 31 vulnerability factors, 11 current adaptations and 11 proactive adaptations.*

***Keywords* :** - .

INTRODUCTION

Flood is one of the major and frequent disasters in Indonesia. EM DAT (2012) has described the impacts of flood in Indonesia since 1900. It identified a growing pattern in term of the number of floods and the flood scale. Figure 1 illustrates the pattern of flood and its impacts in Indonesia. The issue of climate change has also increased the probabilities of flood in the future. Hidayat et al. (2008); Cruz et al. (2007); Santoso and Forner (2006) have identified that the climate change will make more frequent intensity of high rainfall. As a result, the probability of flood in the future will increase as well.

One of the flood prone areas in Indonesia is Centini Village, a village in Bengawan Solo River Catchment Areas (Figure 2). Ce ntini has suffered from flood due to water spill from the river and local rainfall. A low lying areas (with topography from 4.0 m to 6.4 m from sea level in Figure 2) in the village indicates that Centini is threatened area by flood. Based on Figure 2, the embankment height is also around 6.4 up to 9 m from the sea level. Therefore, all the areas in the village is lower than the embankment. Those situations cause the village prone to flood.

The village which is also located near to Jabung Swamp Area has a high probability to be inundated. The swamp is used for temporary natural dam. In the case of high water level in the river, the water will be discharged to the swamp. Since there is no hard structure built in the swamp, some of the water in the swamp can cause flood in the village. One of the big floods in Centini occurred in the end of 2008 up to the beginning of 2009. The 2008 Lamongan Flood had major impacts on the village. 1.120 were counted as

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the number of inundated houses, and number of evacuated villagers for about 3.374 people. In sum, the flood had caused damages/losses for about US$ 27.5 Million in the municipality (Lamongan Municipality, 2008). The flood is identified as an extreme flood in Centini Village. Besides that, Centini is also suffered from the small scale flood. The interview in the mid of 2010 indicates that the small scale floods occurs annually and mostly only affect the lowest part of the village such as paddy fields near the swamps. Furthermore, Hidayat et al. (2008) also identifies that the areas of Bengawan Solo River Catchment areas are affected by the climate change through the increase on rainfall scale and intensity. Therefore, Centini Village is one of the vulnerable villages to flood in Indonesia.

Figure 1 Historical floods' impacts in Indonesia since 1900. http://www.emdat.be/result-country-profile.
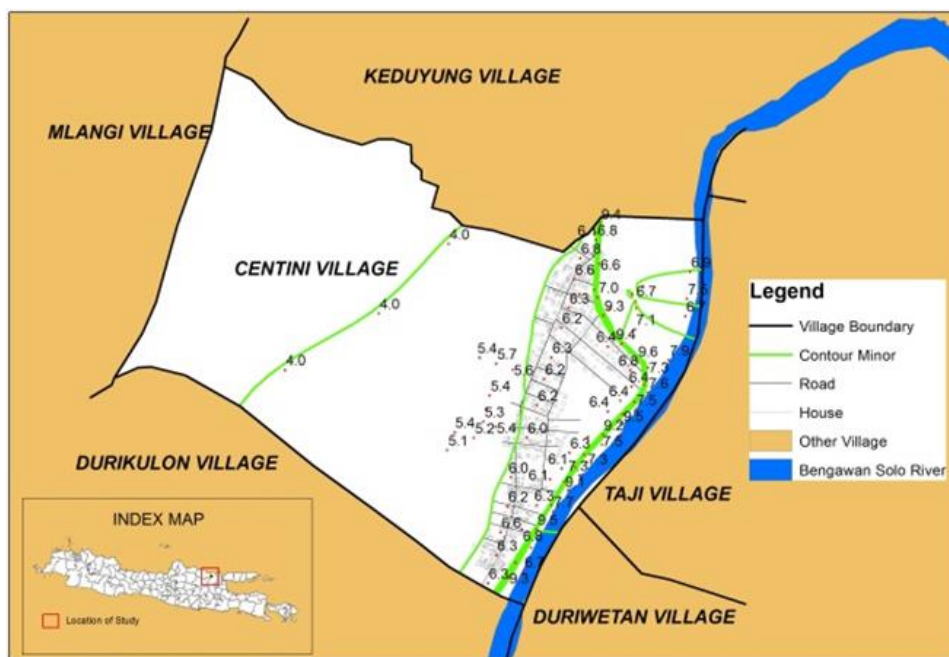
Figure 2 Map of Centini Village and its hotspots indicating the topography.

The village which is also located near to Jabung Swamp Area has a high probability to be inundated. The swamp is used for temporary natural dam. In the case of high water level in the river, the water will be discharged to the swamp. Since there is no hard structure built in the swamp, some of the water in the swamp can cause flood in the village. One of the big floods in Centini occurred in the end of 2008 up to the beginning of 2009. The 2008 Lamongan Flood had major impacts on the village. 1.120 were counted as the number of inundated houses, and number of evacuated villagers for about 3.374 people. In sum, the flood had caused damages/losses for about US$ 27.5 Million in the municipality (Lamongan Municipality, 2008). The flood is identified as an extreme flood in Centini Village. Besides that, Centini is also suffered from the small scale flood. The interview in the mid of 2010 indicates that the small scale floods occurs annually and mostly only affect the lowest part of the village such as paddy fields near the swamps. Furthermore, Hidayat et al. (2008) also identifies that the areas of Bengawan Solo River Catchment areas are affected by the climate change through the increase on rainfall scale and intensity. Therefore, Centini Village is one of the vulnerable villages to flood in Indonesia.

Even though there are some varieties in vulnerability terminology, Pamungkas et al. (2009) defines vulnerability as community performances on responding hazards. It also indicates that the performances are varies in terms of space and time. Those varieties of level are the effects of adaptations in the community. The adaptation itself is determined as any actions to reduce the impact of hazards (as defined by Biesbroek, Swart, & Van Der Knaap, 2009; Smit & Wandel, 2006). In the case of successful adaptations, the level of vulnerability will be lower in the future rather than in current situation. Those gaps between the levels of future and current vulnerability can also be called as resilience. This conclusion considers several key meanings of resilience (Masten, Best and Garmezy in Glantz & Sloboda, 1999).

The relation among adaptation, vulnerability and resilience is illustrated diagrammatically in Figure 3. Based on the diagram, to enhance community resilience in Centini Village, this paper will elaborate the vulnerability factors and current adaptations. The vulnerability factors will indicate the key elements of community for a better coping ability to reduce the impact of hazards in the future. Moreover, the identification on current adaptations will give a judgment on current stage of community adaptation in the disaster risk management context. The current stage is a valuable information in suggesting more comprehensive adaptations following the stages in disaster risk management cycle. Therefore, identifying vulnerability factors and community adaptations are two of the major inputs for enhancing community resilience. Those two aspects are the main concern in this paper.
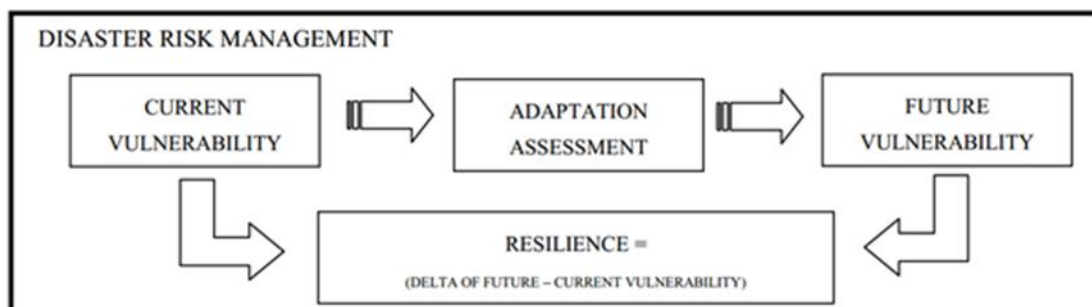
Figure 3 relation among vulnerability, adaptation and resilience (Pamungkas *et al.*, 2011)

METHODS

To identify vulnerability factors and adaptations, a Delphi technique is employed. The technique is aimed to build a consensus among stakeholders. The consensus is then used a basic rationale for stakeholders' opinion in suggesting relevant vulnerability factors to flood in Centini Village. To have a consensus, analysing the output of Delphi questionnaire often rely on the frequency of stakeholders opinion such in Bunting (2008); Briedenhann & Butts (2006). Consequently, the analysis process will reduce the richness of stakeholders' comments and expertise. On other hand, Delphi Technique is part of the qualitative analysis (Briedenhann & Butts, 2006). Consequently, the Delphi technique needs to understand stakeholders' comments to support the analysis process (Merriam in Franklin & Hart, 2007). Therefore, to analyse the output of Delphi questionnaire, this paper will need to

collaborate a quantitative and qualitative approaches. Four steps of analysis are made as follows;

1. Comparing the changes on the number of agreed stakeholders in the first and second rounds of Delphi questionnaires. If the number of agreed stakeholders on one factor increases with high number of agreed stakeholders, that factor can be defined as relevant factors. The increased number of agreed stakeholders means that the number of agreed stakeholders in second round is higher than in the first round.
2. Study on vulnerability which is a context-specific (Pamungkas *et al.*, 2009) requires different treatment on the stakeholders' comments on particular factors. Local stakeholders are valued more relevant than stakeholders from outside the case study because the local stakeholders are the ones experiencing the floods.
3. Study on vulnerability which is also a multidisciplinary approach (Pamungkas *et al.*, 2009) requires a wide range of aspects to be counted in selecting relevant factors. Those multi-aspects on the factors require different treatment to the stakeholders with a specific background or expertise. For example, the factor of community health as one of the potential factors, will be more relevant to be commented by the Health Agency rather than other stakeholders. Therefore, those stakeholders who have a relevant expertise to the factors will be considered more important to others.
4. To validate the outputs in point 1-3, official data are required. The data will be provided particularly for the undefined relevant factors based on the process in point 1-3.

Relating to the explanation above, stakeholder selection becomes one of the critical stages of the research. Since the research employs qualitative analysis, the stakeholders selection will be done by non probabilistic sampling process. The non probabilistic sampling will identify stakeholders based on their relevancy to the research's purposes. The stakeholders are identified as persons from multidiscipline background who understand and participate in the flood in Centini Village. This definition is influenced by the characteristics of vulnerability study particularly on the context-specific and multidisciplinary approach. To select relevant stakeholders, Stakeholder Analysis framework from McCracken and Narayan (1998) is used. At the first stage, small interview processes are conducted to define potential stakeholders resulting 31 stakeholders for this case study. Those 31 stakeholders are analysed through the framework resulting 18 relevant stakeholders. To have a full understanding on the characteristics of stakeholders, grouping process is determined into 4 groups as on the Table 1.

All the stakeholders receive both rounds of Delphi questionnaires. Care NGO does not return the two rounds questionnaires. Moreover, Bengawan Solo River Board prefers to have interview instead of filling the questionnaire. For the Provincial Disaster Management Board, the second round responses are suggested to have the same responses in the first round. Since there are 16 out of 18 stakeholders returning the questionnaire in both rounds, the outputs of Delphi questionnaire are still valid to analyse the vulnerability factors.

Table 1 Relevant stakeholders and their grouping

	Non-Governmental Organization	Governmental Organization
Local Stakeholders	1. ELSAP (Government Analysis Research Centre). 2. Centini Informal Leader. 3. Director of Kidung Rakyat Local Radio.	4. Laren Regency Chairperson. 5. Centini Head Village.
Stakeholders from outside the case study	6. TAGANA (Community-based Youth Group on Disaster Response). 7. JAMAL (Lamongan's People Network). 8. Care NGO 9. Indonesian Red Cross, Lamongan Branch.	10. Municipality safety Agency and the Protection of the Public (Bakesbanglinmas). 11. Irrigation Agency. 12. Bengawan Solo River Board. 13. Unit for Rapid Response. 14. Municipality Development Planning Board. 15. Social, Worker and Transmigration Agency. 16. Health Agency. 17. Municipal Level of Police Department (Polsek).

18. Provincial Disaster Management Board.

RESULTS

The Delphi questionnaire is run to validate 29 potential vulnerability. Those 29 potential factors are in Table 2. The potential vulnerability factors are a simple version of 37 preliminary factors derived from literature. The process is important to make a clear massage to the stakeholders in Delphi questionnaire. It is important since the stakeholders have varieties of educational background and positions. Therefore, the factors in the questionnaire represent some of the factors derived from the literature or has the similar meaning with a factor derived from literature with different terminology.

Table 2 Factors in the questionnaire and derived from literature

No	Factors in the Delphi questionnaire	Preliminary factors derived from literature
1.	No. of disabled people	Special needs populations and ability to swims.
2.	Attitude to disaster and disaster management	Attitude of population to disaster, participation in disaster management and ability to swim.
3.	Community involvement in disaster management	Participation in disaster management.
4.	Level of community trust of formal and informal leaders	Trust in the authority figure
5.	Ownership of communication technology	Telephone connection (communication), Communication.
6.	Building/Housing location in inundation areas	Housing in risky areas.
7.	Insurance Membership	Levels of individual economic reserves and informal and formal insurance.
8.	Food availability in emergency situation	Food security in emergency events.
9.	Government aids	Government aids/grants.
10.	Social interaction in the community	Social interaction.
11.	NGO involvement	Non governmental organizations.
12.	Level of community collectiveness	Degree of collective responsibility and lack of participation in disaster.
13.	Infrastructure availability	Infrastructures and regional transport.
14.	Accessibility	Accessibility
15.	Availability of emergency facilities	Critical facilities and utilities.
16.	Inundated areas	Topography
17.	Variances of community economic sources	Economic diversity, Level of community economic reserves.
18.	Early warning system	Presence of early warning system.
19.	Coordination	Government official’s plans, organisational systems and government services.
20.	External support	External support provided by friends, and private donors.
21.	Land ownership	Level of community economic reserves.
22.	Number of elderly people	Age.
23.	Building Materials	Building materials.
24.	Income	Income.
25.	Family savings	Level of community economic reserves.
26.	Availability of spatial plan	Government’s official plans.
27.	Population density	Population density.
28.	Government services .	Government
29.	Investments	Investments.

The 37 factors derived from literature were grouped into 9 groups as a consequence of vulnerability dimensions. Pamungkas et al. (2009) identifies the three layers of society (individual, community and social network) as one of vulnerability dimensions. Consequently, it should be highlighted in discussing

vulnerability. Moreover, the multidisciplinary approach on vulnerability study directs the discussion not only on social aspect but also on economic and physical aspects of the society. Therefore, the 9 groups of preliminary factors derived from literature are the group of individual-social, individual-economic, individual-physical, community-social, community-economic, community-physical, social network-social, social network-economic and social network-physical. Those groups are important to cover a high degree of previous studies on vulnerability to this research.

From the 29 potential factors in the questionnaire, 19 factors derived from literature are agreed to be relevant to the case study in a firm manner. The firm conclusion are made by considering a high number of agreed stakeholders and its convergence. Moreover, stakeholders also agree on 8 new factors derived from stakeholders' opinions. A convergence in Delphi analysis context means an increase number of agreed stakeholders from the first iterations to the second one (Linstone & Turoff, 1975). Unlikely, the 2 factors derived from literature and 2 factors from stakeholders' opinions are also confirmed to be irrelevant as a result of low number of agreed respondents, no significant comments and divergence on the number of agreed respondents. As a result, based on the first step of the method, 27 factors are accepted as relevant vulnerability factors and 4 factors are irrelevant vulnerability factors in the case study.

Table 3 The analysis process on vulnerability factors based on the first step of the method (tallying).

No	Vulnerability Factors	Number of agreed stakeholders									
		1st Round – Group					2nd Round – Group				
		1[1]	2[2]	3[3]	4[4]	TOTAL	1	2	3	4	TOTAL
Number of Stakeholders within the group		3	3	8	2	16	3	3	8	2	16
Factors derived from literature											
1.	No. of disabled people	0	0	2	0	2	0	0	2	0	2
2.	Attitude to disaster and disaster management	3	3	7	2	15	3	3	8	2	16
3.	Community involvement in disaster management	3	3	8	2	16	3	3	8	2	16
4.	Level of community trust of formal and informal leaders	3	2	8	2	15	3	2	8	2	15
5.	Ownership of communication technology	3	2	8	1	14	3	2	8	2	15
6.	Buildings/houses location in inundation areas	3	2	8	1	14	3	2	8	1	14
7.	Insurance membership	0	1	2	0	3	0	1	2	0	3
8.	Food availability in emergency situation	3	1	8	2	14	3	1	8	2	14
9.	Government aid	3	2	7	2	14	3	2	7	2	14
10.	Social interaction in community	3	3	7	2	15	3	3	8	2	16
11.	NGOs involvement	3	3	8	2	16	3	3	8	2	16
12.	Level of community collectiveness	3	3	8	2	16	3	3	8	2	16
13.	Infrastructure availability (e.g. schools, health centre, mosques, etc.)	3	1	7	2	13	3	2	8	2	15
14.	Accessibility	3	2	8	2	15	3	2	8	2	15
15.	Availability of emergency facilities (e.g. boats, shelters, evacuation areas, etc.)	3	2	8	2	15	3	2	8	2	15
16.	Inundated areas	3	3	8	2	16	3	3	8	2	16
17.	Variances of community economic sources	3	3	7	2	15	3	3	7	2	15
18.	Early warning system	2	1	8	2	13	3	2	8	2	15
19.	Coordination	3	3	8	2	16	3	3	8	2	16
20.	External support	3	3	7	2	15	3	3	8	2	16
21.	Land ownership	2	1	7	2	12	2	2	7	2	13
Factors derived from stakeholders opinions											

[1] Local non-government bodies of Laren Regency
[2] Outsider non-government bodies of Laren Regency
[3] Outsider government bodies of Laren Regency
[4] Local government bodies of Laren Regency

No	Vulnerability Factors	Number of agreed stakeholders									
		1st Round – Group					2nd Round – Group				
		1[1]	2[2]	3[3]	4[4]	TOTAL	1	2	3	4	TOTAL
Number of Stakeholders within the group		3	3	8	2	16	3	3	8	2	16
22.	Swamp silting up	1	0	0	0	1	3	3	7	1	14
23.	Land conversion from swamp to the aquaculture.	1	0	0	0	1	1	2	6	1	10
24.	Drainage system.	1	0	0	0	1	3	3	7	2	15
25.	River embankment reconstruction	0	0	1	1	2	3	3	7	2	15
26.	Community perception on flood	0	0	1	0	1	2	3	4	2	11
27.	Infrastructure redevelopment	0	0	0	0	0	3	3	7	1	14
28.	Community knowledge on flood	0	0	1	0	1	2	3	6	2	13
29.	Government readiness	0	1	0	0	1	3	3	7	2	15
30.	Culture	0	0	1	0	1	0	0	3	0	3
31.	Political commitment	0	0	0	0	0	0	0	1	0	1

NOTE : [shaded] = Agreed Factors
[blank] = Disagreed Factors

Others factors excluding the 31 factors in Table 3 need to be examined in detail due to the divergence in stakeholders' opinions and unclear consensus among stakeholders. Consequently, after assessing those factors by the first step of the method, further assessments (steps 2,3 and 4 of the method) are needed to validate the factors in a concise manner. Understanding stakeholders' comments or rationales and their backgrounds are important to validate their significance of their judgements. Therefore, Table 4 includes stakeholders' comments of their judgments and their positions. Based on Table 4, 6 factors are relevant factors, 5 factors are irrelevant for this case study and 2 factors need to be changed to other new names of factors to represent relevant meaning.

Table 4 The analysis process on vulnerability factors based on the second, third and fourth steps in the method as a continuing the first step in Table 3

No	Vulnerability Factors	Number of respondents who agree									
		1st Round – Group					2nd Round – Group				
		1[5]	2[6]	3[7]	4[8]	TOTAL	1	2	3	4	TOTAL
Number of Stakeholders within the group		3	3	8	2	16	3	3	8	2	16
Factors derived from literature											
1	Number of elderly people	3	2	6	0	11	2	2	5	0	9
		The main argument from most respondents who agree is in a general sense. Otherwise, more contextual reasons come from different respondents who disagree. Stakeholder from The Health Agency (the most relevant stakeholders' background) suggests that elderly villagers will not affect the vulnerability level as they are still strong and hardworking. All local government bodies (group 4) disagree to include the factor. Moreover, there is a decrease number of disagreed stakeholders in Group 1, local non-government bodies.									
2.	Building Materials (brick or wood houses)	3	1	7	1	12	3	1	7	1	12
		JAMAL, Red Cross, Centini head villager, and provincial government argue that the quality rather than type of the building materials will determine their vulnerability. Therefore, the factor will be changed into the quality of building materials.									
3.	Income	2	0	5	2	9	3	0	5	2	10
		All the local stakeholders (5) agree. All respondents who agree from the local area state the relevancy of the factors to my case study. The income is the main source of funds in the recovery process.									
4.	Family savings	2	0	1	2	5	2	0	1	2	5
		There are four local respondents who agree and only one (ELSAP) disagree on the factor. The latter does not provide an explanation. The Centini Head of Village, as one of the agreed local respondents argues									

[5] Local non-government bodies of Laren Regency
[6] Outsider non-government bodies of Laren Regency
[7] Outsider government bodies of Laren Regency
[8] Local government bodies of Laren Regency

No	Vulnerability Factors	Number of respondents who agree									
		1st Round – Group					2nd Round – Group				
		1[5]	2[6]	3[7]	4[8]	TOTAL	1	2	3	4	TOTAL
Number of Stakeholders within the group		3	3	8	2	16	3	3	8	2	16
		that the villagers regularly attend their local bank. Based on outside respondents, only one of them agree on the factor while others (11) disagree. The only one who agree is from Social, Worker and Transmigration Agency which is the most relevant government bodies to the factor. He argues that the saving factor will influence the recovery process. Therefore, since the majority of local and the most relevant outsider respondents agree with valid reasons, I include the factor as one of my vulnerability factors.									
5.	Availability of spatial plan	0	2	7	1	10	2	3	7	1	13
		Respondents who agree increases (10 to 13) but in the general understanding of arguments. They value the importance of having the plan in minimizing a flood's impacts. However, they still have no idea of how to integrate it within flood risk management. Moreover, according to the Municipality Development Planning Board, the village is not covered by their local master plan. It means that the plan has no contribution to flood risk management in my case study for the current situation in the village.									
6.	Population density	1	1	7	0	9	2	1	7	0	10
		Respondents who agree increases from 9 to 10 respondents. They propose to use the factor of the population number rather than the population density. They consider that the population number mainly drives the population density. So they agree on this factor in the sense of responding to population numbers. Conversely, the majority of local stakeholders disagree with this factor with arguments of low and uniform density within the area. Therefore, I justify this factor as irrelevant factors for my case study and change it into population number factor.									
7.	Government services (e.g. building codes, permits, etc.)	1	1	6	2	10	2	1	6	2	11
		The majority of respondents agree on this factor with significant comments. On the other hand, the respondents who disagree provide no significant reasons. Some of disagreed respondents consider that this factor has little correlation with flood risk management such as Health Agency, Red Cross and local radio. Their arguments are weak as their professional works are in different areas. Only the Municipal Planning Board which has significant interests disagrees with this factor. He values it as irrelevant factor because he suspects that the villagers have a strong opposition to the government instruments. He believes that the government services in that area do not exist. The other disagreed respondent, which is TAGANA, refuses to make further comments on second round.									
8.	Investment	0	0	1	1	2	0	0	2	1	3
		The number of respondents who agree is insignificant – only 3. However, Social, Worker and Transmigration Agency, Centini Head of Village and Public Works Agency provide valid responses. They argue that investment can finance the rehabilitation processes. Conversely, a strong opposition on this factor comes from most respondents. They believe that the investment in Centini Village is insignificant since the village is on a basic economic level. They also add that not many investments come from non villagers. Since both sides have significant reasons, the majority supporting the factor conclude the factor is not one of my vulnerability factors.									
Factors derived from stakeholders opinions											
36	Number of babies	0	0	1	0	1	1	0	5	1	7
		The majority of respondents disagree with the reason that there is an insignificant number of babies in the village. Conversely, Health Agency suggests that the number of babies is significant based on their annual data. In addition, the number of respondents who agree and disagree are even. Since the factor is in the main field of Health Agency, and the agency provides data to support his argument, I believe that the factor is significant for my case study.									
9.	Nutrition status	0	0	1	0	1	2	0	5	0	7
		Same as no. 8.									
10.	Chronic diseases	0	0	1	0	1	0	0	4	0	4
		Only four respondents agree with this factor in second round. The Health Agency agrees that this factor will cause the victims to be at greater risk. However, he then emphasizes that the effect of floods on chronic diseases cannot be identified as the development of chronic diseases over a longer time. Therefore, I believe that this factor is not one of my vulnerability factors.									
11.	Community knowledge on flood	0	0	1	0	1	2	3	6	2	13
		The argument to include this factor is similar to the factor for Tabel 3 No. 26. The factor of attitude to flood will represent this factor as one of my vulnerability factors. ELSAP, Unit for Rapid Response and Provincial Disaster Risk Management Board are the three disagreed respondents.									
12.	Gender	0	0	1	0	1	1	1	2	2	6

No	Vulnerability Factors	Number of respondents who agree									
		1st Round – Group					2nd Round – Group				
		1[5]	2[6]	3[7]	4[8]	TOTAL	1	2	3	4	TOTAL
Number of Stakeholders within the group		3	3	8	2	16	3	3	8	2	16
	involvement	The majority of disagreed respondents argue that gender will not determine community involvement. They justify this by saying that the involvement of the community has been equally contributed to different functions and activities between male and female. There is no significant issue on segregation among gender not only in disaster risk activities but also in social life. Therefore, I eliminate this factor in my research.									

NOTE :

- (grey) = Agreed Factors
- (white) = Disagreed Factors
- (green) = Changed Factors

Table 3 results 27 relevant factors and table 4 results 8 relevant factors (6 relevant factors and 2 factors with some changes on the label). In sum, the relevant vulnerability factors are 35 factors. Since the factor of land conversion from swamp has similar meaning to the factor of swamp silting up, land conversion is used to represent those two factors. In addition, the factor of attitude to disaster and disaster management will include the meaning of community perception on flood and community knowledge. Those two factors are included in the attitude factor to simplify the measuring process for further assessment on vulnerability modelling. In conclusion, 31 final vulnerability factors have been determined as on Table 5 .

Table 5 Final vulnerability factors

No	Final Vulnerability factors	No	Final Vulnerability factors
1.	Attitude to disaster and disaster management	17.	Coordination
2.	Community involvement in disaster management	18.	External support
3.	Level of community trust of formal and informal leaders	19.	Land ownership
4.	Ownership of communication technology	20.	Land conversion
5.	Buildings/houses location in inundation areas	21.	Drainage system
6.	Food availability in emergency situation	22.	River embankment reconstruction
7.	Government aids.	23.	Infrastructure redevelopment
8.	Social interaction in community	24.	Government readiness
9.	NGOs involvement	25.	Quality of building material
10.	Level of community collectiveness	26.	Income
11.	Infrastructure availability (e.g. schools, health centre, mosques, etc.)	27.	Family savings
12.	Accessibility	28.	Number of population
13.	Availability of emergency facilities (e.g. boats, shelters, evacuation areas, etc.)	29.	Government services (e.g. building codes, permits, etc.)
14.	Inundated areas	30.	Number of babies
15.	Variances of community economic sources	31.	Nutrition status
16.	Early warning system		

Following the result on 31 final vulnerability factors, reviewing back the stakeholders' comments on proposing relevant factors in Delphi questionnaires is the main input for defining current adaptations. Current adaptations are defined as any efforts undertaken to reduce current vulnerability level. Table 6 lists current adaptations based on the final vulnerability factors. It also shows the position of the adaptations in disaster risk management (DRM) cycle. The cycle follows the idea from Shah Alam Khan (2008); Moe et al. (2007); FEMA (2006); Atmanand (2003) that are mitigation, preparedness, response and recovery. Based on the position, 7 out of them

sit in responses stage. 3 of them are in mitigation and recovery. And one of them is in preparedness but not in regular basis. Therefore, those positions indicate that current adaptations are in a reactive basis rather than proactive. Moreover, the adaptations are also incomplete actions for an integrated DRM.

Table 6 Current adaptations and their position in the DRM cycle

No	Current Adaptations	Position in DRM cycle
1.	Making an Antru (A mezzanine to make temporary two-storey houses during flood).	Responses
2.	Running disaster trainings after the big flood in 2008.	Preparedness but not in a regular basis
3.	Sounding the coming floods	Responses
4.	Contacting aid donors after floods hit the village.	Responses
5.	Allocating government funds for rehabilitation and reconstruction after floods.	Responses
6.	Making a collaboration between municipal government and villagers to response coming severe floods	Responses
7.	Forming the implementing unit for disaster management in emergency situation.	Responses
8.	Programming and budgeting for building and maintaining the river embankment infrastructure.	Mitigation and recovery
9.	Providing community health centre particularly for maternal and child health.	Mitigation and recovery
10.	Applying social sanction for non participate villagers in responding floods.	Responses
11.	Having more than one incomes.	Mitigation and recovery

DISCUSSION

Understanding the outputs in the Result Section, 3 main points need to be discussed thoroughly. Those 3 points are the analysis type of Delphi questionnaires in determining the vulnerability factors, current adaptations and proposed adaptations for a better community resilience to flood.

For the analysis type of Delphi questionnaires, this paper proposes that combining the quantitative and qualitative approaches will increase the degree of validity. The quantitative approach such as tallying increases the consistency of the analysis. The use of quantitative approach also benefits in easy validation on the all stakeholders' opinions. For example, it is easy to understand the majority of stakeholders proposing a factor by counting the numbers of agreed stakeholders. Therefore, involving quantitative approach in analysing Delphi questionnaire is still important.

In the mean time, relying solely on the tallying process will screw the urgency of stakeholders' comments and their expertise. Consequently, the analysis outputs can be meaningless in understanding the case study. Table 4 has shown that some of the factors are clarified after understanding stakeholders' comments and expertise.

In terms of the comments, some of their comments are valuable to understand the significance of their suggestions. Instead, some of their comments are insignificant to support their suggestions. Therefore, understanding their comments increases the degree of validity in analysing the Delphi outputs. This can be done by using content analysis, grounded theory or simply just finding key meaning of the stakeholders comments.

Since vulnerability is a multidisciplinary topic, having a stakeholder who understand multidiscipline is highly difficult. Consequently, some stakeholders have expertise or more comprehensively understanding in a discipline compared to others. Those positions or expertise are significant to increase the validity of stakeholders' comments. Those position is valued as their knowledge and experiences in a discipline. A stakeholder with a broaden knowledge and experience gives a significant comment. Therefore, the position is also important to be included in understanding stakeholders' comments.

Likewise other qualitative approach, including the stakeholders' comments and positions in the

analysis process is making the validity process a challenging task. In this case, being a transparent in the analysis process (like in Table 4) is one of the validity type. In addition, stakeholders' comments are also validated by comparing them with the official data. Those two ways of validity processes in qualitative approach can be expanded to other relevant validity.

From Table 6, 11 current adaptations as a response to 31 final vulnerability factors focus on a responses stage of DRM. Those adaptations can be said as a reactive actions. These actions are not sufficient particularly in enhancing community resilience. A low level of resilience can be seen from the villagers' low level of wealth fare and flood impacts in the village compared to others. In 2008, the village has a high percentage (24%) of under wealth households indicating that almost a quarter of villagers are poor (Centini Village Monograph, 2008). Moreover, the 2008 Lamongan flood had the most impacts in the Regency of Laren, Maduran, Babat, Glagah and Karang Binangun (Lamongan Municipality, 2008). Centini is one of the villages in Laren Regency.

To enhance community resilience, considering current adaptations in order to minimize the performance of vulnerability factors is a rationale basis for proposing proactive adaptations. Proactive adaptations can be from other cases/experiences or knowledge. Both of them can be selected by considering relevant literature. This reviewing literature process results 3 groups of the adaptations as follows;

1. Spatial Plan (Biesbroek et al., 2009; Fleischhauer, 2008; Dewan et al., 2007; and Billa & Shattri, 2006): reforestation, relocation, better house construction and better infrastructure.
2. Economic development: cash transfer programs (Iqbal, 2008), insurance (Kousky & Kunreuther, 2009; Kron, 2009; Hofman, 2007; and Atmanand, 2003), creating alternative sources of income (based on ELSAP suggestion) and increasing the level of income of the villagers (Rayhan & Grote, 2010; Patil et al., 2009; and Ibrahim et al., 2009).
3. Proactive community actions: regular community meetings (Reimer et al., 2008); Jones et al., 2008; Wagner, 2008; Godoy et al., 2007; and Haan, 2001), building a strong network (Cook, 2005 and Baerenholdt and Aarsaether, 2002) and changing the form of the responsible board for disaster management.

Proposed adaptations above which are suggested from the literature need to be clarified into further assessment. Modelling which can integrate the current vulnerability, current adaptations and proposed adaptations simultaneously will assess the effectiveness of both types of adaptation. The effective adaptations indicate a decrease vulnerability from current to possible future levels. A decreasing levels is also indicating an increasing community resilience. Therefore, a further assessment using modelling approach among the vulnerability factors, current adaptations and proposed adaptations can determine appropriate community actions for enhancing community resilience to flood.

CONCLUSION

In enhancing community resilience, I propose to consider the vulnerability factors and current adaptations. The factors indicate the critical points of the successful disaster risk management (DRM). Moreover, the adaptations are important actions particularly in changing the vulnerability from one level to others. The adaptations are responses to vulnerability factors. Therefore to enhance community resilience, integrating vulnerability factors and the relevant adaptations are highly important.

Having the 2 rounds Delphi questionnaires to 18 stakeholders, this paper proposes 31 vulnerability factors and 11 proactive adaptations. The factors are a mix of physical, economic and social aspects as well as representing the three layers of societies (individual, community and social network). Furthermore, those proactive adaptations are believed to be important to support the 11 current adaptations in the DRM cycle framework.

A further assessment will be needed particularly for modelling process. Integrating those factors and adaptations in the modelling process will describe the relationship among community's sub systems in order to enhancing community resilience. The modelling process will also assess the effectiveness of adaptations to decrease vulnerability level. Those effectiveness assessment is significant inputs for public policy in enhancing community resilience. Therefore, modelling process with the integration among vulnerability factors and adaptations is

needed to be a rationale basis of public policy decision making in enhancing community resilience.

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19 Mitigation and Adaptation Planning of Climate Change in East Kalimantan: A Critical Review

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Abstract – *Extreme weather events related to climate change in the future are likely to increase a number and scale of disasters. In order to prepare for these changes and the impacts they will have on natural systems and human communities, it is need "climate change adaptation". Understandably, much attention has been focused to date on "climate change mitigation," or efforts to reduce greenhouse gas (GHG) emissions in the atmosphere and help slow the rate of climate change. Climate change adaptation and mitigation are related, and both are important for local government because adaptation to climate change needs to be on going. Successful adaptation will require not only good information about climate change, and prioritization of actions, but also the ability to implement responses and modify hose responses over time. This paper summarizes some literatures to demonstrate that there are some different inclusive partnership approaches that have been taken to conduct mitigation and adaptation planning in East Kalimantan. Those approaches of climate change mitigation and adaptation planning provide better understanding on the usage of planning in any different levels of mitigation and adaptation and its limitation.*

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Keywords: *Climate change, Adaptation, Mitigation, Planning, East kalimantan*

I. INTODUCTION

Climate change is one of the most critical, and also most daunting, challenges facing policymakers in the twenty-first century. Indonesia, including East Kalimantan, is vulnerable to many expected impacts from climate change. These impacts have become more complicated by the El Niño which leads to extreme weather events on a cyclical basis and also linked with these events, droughts, major forest fires, and haze (Barber 2008). The frequency in El Niño events is positively correlated with climate change. East Kalimantan has 194,000 ha of land that is vulnerable to coastal flooding related to the estimation that sea levels are going to rise by 20 cm by 2030 because of the climate change.

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Although the area that is vulnerable to coastal flooding is relatively small, it contains some of the province's largest assets.

Moreover, East Kalimantan consists of nearly two million square km of land which support extremely high levels of biodiversity, which in turn, support a diverse array of livelihoods and ecosystem services. Seymour (2008) had been identified that more than 50% of East Kalimantan's 13 million hectares were forest areas and contain 2100 forest species. At present, forest cover has been lost due to conversion for agriculture and plantations, illegal and large scale logging, fires, mining, and infrastructure development. Loss of forest cover, riparian buffers, and mangroves significantly increase regional and local vulnerability to climate variability and climate change, and increase carbon emissions.

Related to the fact that climate change also potentially has impact on East Kalimantan, it is indisputable that the causes of climate change have been made in East Kalimantan itself. Considering

the large geographic coverage of East Kalimantan, its support of biodiversity, and the range of land use policies and allocations across administrative hierarchies in the country, many initiatives, action plans, and regulations should be implemented at the sub-national levels of province and district, such as adaptation and mitigation planning.

Here introduce the paper, and put a nomenclature if necessary, in a box with the same font size as the rest of the paper. The paragraphs continue from here and are only separated by headings, subheadings, images and formulae. The section headings are arranged by numbers, bold and 10 pt. Here follows further instructions for authors.

II. METHODS

The assignment consists of review of existing literatures. Throughout the review, the focus has been on collecting practical information on different projects and programmes that capture the diversity of various efforts in the region, including location, scale, sector, strategic emphasis and the climate impacts being addressed. While conducting a review of adaptation and mitigation planning in East Kalimantan could take many months, this endeavour, including literature review, and report writing took fewer days. This has meant that the authors have had to make choices about which projects and programmes to focus attention on. Furthermore, with the exception of visiting to project sites, the authors were only able to review projects and programmes where there was written documentation. This has limited the review given that many relevant activities and projects have not yet been documented. Equally, a reliance on English-language documentation has also excluded some projects and programmes. Finally, some bias in the review may have occurred as a result of organisations emphasising the positive aspects of programming over negative ones. In order to mitigate this, the researchers have used their own judgement to assess the success and impact of such programmes.

III. Discussion

This section discusses key mitigation and adaptation concepts, and compares the concept based on some researches to the actual projects and programmes in East Kalimantan.

3.1. Mitigation

Mitigation is defined by Ahuja (2007) in the report for IPCC as "*an anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks*". It is believed that the first task is to address the root cause by reducing greenhouse gas emissions from human activity. The means to achieve this are very contentious, as it will require radical changes in the way many societies are organized, especially in respect to fossil fuel use, industry operations, urban development and land use.

3.2. Adaptation

Adaptation is also defined (Ahuja 2007) as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". This second task is known to manage impacts of the climate change. Future impacts on the environment and society are now inevitable, owing to the amount of greenhouse gases already in the atmosphere from past decades of industrial and other human activity, and to the added amounts from continued emissions over the next few decades until such time as mitigation policies become effective. We are therefore committed to changes. Taking steps to cope with the changed climate conditions is called "adaptation".

All in all, mitigation refers to those efforts to reduce greenhouse gas emission reductions or enhance carbon storage; adaptation refers to those actions that aim to minimize the negative effects or exploit the potential opportunities presented by climate change. Practitioners need to prepare for and respond to impacts of the climate change through mitigation and adaptation measures. Neither mitigation nor adaptation alone will be sufficient; both approaches are needed for an integrated climate change response strategy in East Kalimantan.

Climate change mitigation and adaptation have some common elements, they may be complementary, substitutable, independent or competitive in dealing with climate change, and also have very different characteristics and timescales (Barker 2007). Both adaptation and mitigation make demands on the capacity of societies, which are intimately connected to social and economic development. The responses to climate change depend on exposure to climate risk, society's natural and manmade capital assets, human capital and institutions as well as income. Together these will define a society's adaptive and mitigative capacities. Key factors that determine the capacity of individual stakeholders and societies to implement climate change mitigation and adaptation include: access to resources, markets, finance, information, and a number of governance issues.

High levels of awareness and varying levels of concern about climate change coincide with still very limited knowledge in many countries (Directorate-General for Communication of the European Commission 2008; Downing 2008; Dunlap 1998; Leiserowitz 2010; Moser 2008; Newport 2010). The global consensus has developed far faster than a global response. Developing countries now account for such large and growing emissions that they must take action today if climate change is to be mitigated and Indonesia understands this impasse. It has decided to take action to break it and create new momentum in the global negotiations for serious action to combat climate change. For a democratic and decentralized country such as Indonesia, the provincial and district-level governments are at the heart of this challenge. The Provincial Government of East Kalimantan, and the National Council on Climate Change (Dewan Nasional Perubahan Iklim, DNPI) have launched Environmentally Sustainable Development Strategy or also known as east Kalimantan's Green Growth Strategy (Strategi Pembangunan Ramah Lingkungan) to chart a plan for the province.

Recognizing that a degree of climate change is already locked in by recent CO2 rises, and despite current global action, the strategy also explores adaptation measures, which aim to make the province more resilient to climate change. Moreover, this strategy also requires climate change mitigation by focusing on reducing the carbon footprint of its current economic sectors, moving to higher value-added activities and new low-carbon activities, and acting to make the economy and infrastructure resilient to climate change.

IV. ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT STRATEGY IN EAST KALIMANTAN

There are some key elements of the Environmentally Sustainable Development Strategy in East Kalimantan as a holistic approach where mitigation, adaptation, and also economic growth go hand in hand.

4.1 Mitigation

Based on the Master Plan of East Kalimantan (RTRWP 2008-2027), the spatial planning process was started prior to emission reduction targets by optimising East Kalimantan land use. One of the implication of land use plans is reviewing down to 800.000 Ha of original proposal for 1,3 million Ha forest conversion. Another target is using degraded land to substitute forest under threat could avoid emissions from deforestation.

In district scale, the strategy related to mitigation concept has been implemented in Berau in the form of Berau Forest Carbon Program (BFCP) which is a partnership between national, provincial and district governments, civil society, and the private sector to enable Berau to meet its development goals while sustainably managing its forests and delivering effective incentives to reduce emission (Fishbein 2009). The BFCP directly engage target communities to support governance and natural resource management by using its community engagement plan:

- Involvement in low-carbon development strategy
  Meaningfully involve communities in design and oversight of Berau's low carbon development strategy. Forest communities are constructively engaged in BFCP governance and decision making at strategic and operational levels, as well as other important policy dialogs in Berau.
- Free, prior, and informed consent
  Ensure informed consent for all agreements, to be implemented on a sustainable basis.
- Strengthened village institutions
  Help villages develop better governance institutions, ones that will allow for effective community involvement in natural resource management and sustained implementation of BFCP.
- Livelihoods
  Improve livelihoods, including alternative livelihoods that reduce pressure on the environment in the short, medium, and longer terms.
- Benefit sharing
  Establish arrangements for fairly and sustainably apportioned streams of benefits for villages including women, (social services, community infrastructure, etc.)
- Learning
  Document and disseminate learning and scaling-up mechanisms from BFCP's community involvement component.

Although the mitigation concept has been made, there are only fewer examples of mitigation planning implementation have been identified. Harris et al (2008) identified many areas with high carbon stocks under high deforestation threat that would be important to protect if the carbon benefits of avoided deforestation activities are to be maximized in East Kalimantan.

4.2 Adaptation

It has been predicted that impacts of climate change in East Kalimantan are forest fires which also have a direct impact on the physical environment, and diseases or health problems (MoE and UNDP 1998), sea level rise that has serious implications for coastal and inland flooding, Indonesian state border with Malaysia (Hendiarti 2007) and East Kalimantan's largest assets, 86% extensive collar reefs which are considered at risk[9], but there has not found yet any adaptation strategy which can manage these impacts.

Rather than only focus on assessing and communicating vulnerability to climate change, and evaluating co-benefits of adaptation, Fussel and Klein (2004) have suggested several prerequisites for effective planned adaptation by triggering research that may lead to the development of new adaptation options. Watson et al (1998) believed that "because the available studies have not employed a common set of climate scenarios and methods, and because of uncertainties regarding the sensitivities and adaptability of natural and social systems, the assessment of regional vulnerabilities is necessarily qualitative". This is particularly true for developing countries. The problem is exacerbated by the expectation that those with least resources have least capacity to adapt and are most vulnerable to future climate change (Watson et al., 2000). Fussel and Klein have also suggested for identifying and assessing effective adaptation measures, and motivating the provision of additional resources either domestically or internationally, educating people about risks and response options to increase the acceptability of unfamiliar measures and identifying obstacles for implementation of effective measures and suggesting options to overcome them. These suggestions are believed can support the adaptation planning. In addition, Sterrett (2011) has identified some following elements which are crucial for adaptation, such as investing in communities' ability to shape, create, and respond to change by building adaptive capacity starts at the community level which are similar to the Fussel's strategy to educate people. Other elements which are also important are empowering local levels of government to be genuine agents of change for the communities they serve and national planning that is informed by bottom-up vulnerability assessment in order to create an enabling environment for adaptation.

Adaptation is not a choice between reducing general vulnerability and preparing for specific hazards; rather it is a process of assessing and reassessing conditions and information related to climate change impacts and to the factors that leave people unable to adapt (Pettengelle, 2010). Achieving transformational changes in the lives of people living in poverty in a changing climate demands enormous political will and investment. It demands flexibility and learning through every institution, from household to government. It requires an approach that combines bottom-up with top-down processes; local knowledge and scientific knowledge; reducing vulnerability and addressing impacts; specific responses and managing uncertainty; sustainable livelihoods; and change and learning how to change.

Specifically, Novib (2010) has offered five inter-related components needed to achieve the aim of adaptation planning that also support the key elements which have been identified by Sterrett.

- Agricultural adaptation: Using vulnerability assessments to identify specific climate risks facing different livelihood groups in target areas, this component works with smallholders and tries out traditional and innovative strategies that are climate-resilient; Since it is recognised that climate change is an additional threat to food security, it has need and an effort to develop adaptation strategies for the agricultural sector, Better information is required on the role of agroforestry in buffering against floods and droughts from both the biophysical (hydraulic lift, soil fertility) and financial (diversification, income risk) points of view (Verchot et al. 2005).
- Livelihood diversification: This component focuses on the identification of niche products and services, and employment opportunities, as well as the modelling of best practices in promoting economic leadership;
- Strengthening community resilience to climate shocks: This component focuses on improving community-level mechanisms in disaster risk reduction, preparedness and management, as well as micro-insurance schemes;

Ecosystem and Adaptation Network stated that there is an approach to adaptation have gained currency over the past few years, namely Community-based Adaptation have specific emphasis on empowering local communities to reduce their vulnerabilities (Girot 2011).

- Increasing the responsiveness of national governments to climate change: This component looks to co-ordinate the lobbyists and a range of advocacy groups more effectively, facilitating and following up on liaison with the government, conducting media campaign highlighting human impacts of climate change and the required actions, and mass mobilisation activities;
- Regional advocacy, linking, and learning: This component supports stakeholders to advocate policy changes regionally by linking knowledge

gained through advocacy across other organisations.

4.3 Economic Development

Developing economics in Kalimantan by analysing existing competitive strengths and weaknesses and exploring potential new sources of growth (providing less carbon emissions).

4.4 Institutional Enablers

The Fourth Assessment Report of Intergovernmental Panel on Climate Change mentioned the expectation of urban planning can play substantially in adaptation and mitigation is very high. However, there is a lot of scope for doing research still need to be examined further.

Sub-national level planning recognises that vulnerabilities and the capacity to respond are site-specific. Planning at this level can engage local government, businesses, NGOs and the community. Rural and urban development planning will often have a different emphasis. For instance, in rural areas the focus is likely to be on livelihoods, reducing poverty and improving access to public services. Meanwhile, in urban areas, the focus could be on improving infrastructure and building residents' resilience to hazards (UNDP-UNEP, 2011)

V. CONCLUSIONS

Although the review in this article is not sufficient to draw specific frameworks for all types of mitigation and adaptation planning which has been implemented in East Kalimantan, this preliminary work provides general information how the Government of East Kalimantan takes responses for the impact of climate change. Since there are many areas which are potentially for mitigation planning implementation, it will have been beneficial for the government and also for the communities because it can improve the quality of life and allow for effective community involvement in natural resource management. It can be noticed that the adaptation planning in East Kalimantan is not as comprehensive as it has to be related to the key elements from the literatures which are not fulfilled.

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20 The Proposition of The Convergence of Individual and Community Resilience

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Abstract – *An unexpected result from a study of the Quality of Life (QoL) of 85 households in kampong Tunjungan, an informal settlement located in the CBD of Surabaya, Indonesia was the apparent existance of a resilience "tipping" point. The existance of such point would be significant in the resource allocation and programne prioritising. Moreover, further review and reflection of the data suggested a linear relationship of individual resilience up to that tipping point and then creation of additional community resilience and a non linear relationship beyond. Thus, there was an apparent convergence of individual and community resilience whereby the "whole was more than the sum of the individuals". This paper sets out to put the proposition. Certainly, further research is required but the notion of such a covergemce and the possibility of a tipping point are intriguing.*

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I. INTODUCTION

The understanding of individual resilience is largely based upon studies of trauma exposed people who subsequently developed symptoms and sought treatment (Bonanno, 2004). And it was only later longitudinal studies that pointed to the human capacity for resilience (Bonanno et al, 2004) through studies of young people exposed to often horrific and traumatic events who were able to nonetheless transcend them and lead healthy, productive lives (Garmezy, 1974), (Werner et al, 1989). But what was perhaps even more striking was that the youth involved in these studies had no outside intervention or psychotherapy, and appeared to survive, and even thrive, based on their own inner resources (Pransky, 2005). This brought about a research shift from risk factors to one that considered well being and resilience (Bernard, 1991). That lead to the identification of attributes of resilient people that included having a positive outlook, self-esteem, self effacy, critical thinking and planning skills, an ability to delay gratification and instead focus on long term goals, good social s kills and a sense of humor (Resnick, 1993). Subsequent programnes sought to teach or build such competencies using “Learned Optimism”, “Positive Behavioral Support” and “Mindfulness” based interventions from the “outside”. However, some researchers still held that individual resilience was an inherent human capacity that essentially came from “inside” (Masten, 2001). Thus, the human capacity for resilience currently appears to lie somewhere between nature and nurture (Kelly et al, 2013)

A community on the other hand has been defined in different ways depending on the perspective of the discipline. It can be a group of people coming together in physical, environmental, economic, relational, political or social ways (Kumar 2005). People can belong to several different communities that can be characterized in 3 ways as follows (Maguire, 2008):

- Community of Place: defined in physical or environmental terms as a group of people living in the same area (Kelly, 2004).
- Community of Interest: defined as a group of people who have similar characteristics sometimes due to shared values or a shared

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"fate". (Stenekes et al. 2008), (Norris et al, 2008).

- Emerging Communities where there was previously no cohesive and organized community in response to an issue/s.

All 3 potentially have sub groupings but are motivated to act for the benefit of the whole rather than their own (Eggins et al. 2004) though this can and does change with time and context. Thus, Kelly argues that "modern communities are not fixed, and tend to develop on an ad hoc basis according to the needs, desires and goals of [their] members…".

The current thinking therefore is that building resilience requires an integrated approach and a long term commitment to improving three critical capacities: absorptive capacity, adaptive capacity, and transformative capacity (Béné et al., 2012). Absorptive capacity is the ability to minimize exposure to shocks and stresses where possible and to recover quickly when exposed (Frankenberger et al., 2012). Adaptive capacity involves making proactive and informed choices about alternative strategies based on changing conditions and transformative capacity relates to governance mechanisms, policies/regulations, infrastructure, community networks, and formal safety nets that are part of the wider system in which individuals, households and communities are embedded. Transformative capacity refers to system-level changes that enable more lasting resilience and often challenge the status quo in a substantial way (Béné et al., 2012). Each of these capacities is not mutually exclusive and apparently exists at individual, household, community, state, and ecosystem levels.

Nonetheless, operational and programming questions about how to do this and what it might entail remain (Pain et al, 2012). Resilience is seemingly portrayed on one hand as self evident and common sense; but on the other as "conceptually and programmatically elusive". And while a lack of resilience is quite evident in the field; when it is there, is not. Thus, there are questions about what really does constitute resilience, and whether it should be thought of at an individual, community or societal level? What are it's scales and timeframes, is resilience specific to particular risks or more generic and is it the same for a fast onset natural disaster as a slow or protracted one? More importantly, the three critical capacities above focus on the systems rather than the individual (or household) and as such resilience is consequently seen as a property of the system or perhaps community rather than the individual. Those in the field question whether this is correct?

One theme of this conference is that the term 'resilient city' often encompasses physical planning and interventions aimed only at the built environment, the so called "system". However, resilience can only be achieved and sustained through thorough integration of both the built and the social environments. "In this case, we [the conference] ask: how can communities contribute to creating and improving resilience"?

II. BACKGROUND

The approach adopted in this and previous research was to use a Quality of Life (QoL) or "wellness" tool called the DASS42 (the case for it's selection will be discussed later). There are apparently 38 QoL tools (Sharp et al, 2005) and the usefulness of such tools according to Malcolm is to provide "an approximate measure of the right things [as being] more meaningful than an exact measure of the wrong things" (Malcolm M-J, 2006**)**. Polletti perhaps puts it best with the comment that such approaches "aims for better (as opposed to perfect) information with which to make a case for plausible (as opposed to proven) associations" (Polletti, 2004). Thus, the role of the DASS42 is not to show absolute quantitative differences in a research sense but rather to suggest reasonable and credible cause and effect linkages. And hence the second tool for this research. The application of both tools should then throw light on aspects of architecture that contribute to the well being (happiness) of people in informal settlements.

III. TOOLS

For Jacobson the language of this relationship was in the "patterns" that existed in the house. The "Language of Patterns" was developed by Alexander and "in a general sense these patterns are a designer's rules of thumb or intuitive principles that guide them just like it does with our grammatical rules [that] allows us to speak fluently and create well formed sentences". (Alexander et al, 1977). Alexander's position was that "this language [of patterns], like English, can be a medium for prose, or a medium for poetry. The difference between prose and poetry is not that different languages are used, but that the same language is used, differently. …The same is true for pattern languages." He goes on that "it is essential that when you have learned to use the language, that you pay attention to the possibility of compressing the many patterns that you put together into the smallest possible space. You may think of this process of compressing patterns as a way to make the cheapest building which has the necessary patterns in it. It is, also, the only way of using a pattern language to make buildings which are poems". He was later to refer to this as the "Timeless Way of Building" (Alexander, 1979). And as outlined earlier Jacobson et al 25 years later stated that "While there may be many dozens, even hundreds of patterns that go into the making of homes, there is only a handful that we now say are essential…" (Jacobson et al, 2002). The selected 10 Essential Patterns are shown in table 1 below.

Table 1: The 10 Essential Patterns that form the Talk to the Buildings Approach.

Pattern	Definition
1. Inhabiting the site	**If the form of the house doesn't begin by responding to the site, house and site may well end up in conflict with each other**
2. Creating rooms, outside and in	**a lively balance of indoor and outdoor rooms**
3. Places in between	**Places that allow you to inhabit the edge, that offer enough exposure to make you aware of your surroundings, and that provide just enough protection to make that awareness comfortable**
4. Refuge and outlook	**At its simplest we are inside looking out**
5. Private edges, common core	**A good home balances private and communal space throughout**
6. The flow through rooms	**Movement through a room affects the room itself**
7. Composing with materials	**Choosing its materials – to support, frame, fill, cover, colour and texture space – is the act of composing the home**
8. Sheltering roof	**More than any other single element, the form of the roof – as experienced both outside and in – carries the look and meaning of shelter, of home**
9. Parts in proportion	**A home is a hierarchy of parts in proportion**
10. Capturing light	**Good homes capture light – filter it, reflect it – in ways that, no matter the season or time of day, delight their inhabitants**

These 10 patterns has been beneficially used in several situations and one example has been the mapping of these patterns against the spatial areas of 109 houses provided for those affected by the 2004 Asian Tsunami in Tamil Nadu, India (Russell et al, 2008).

The "Talk to the Buildings" approach has several advantages over other more main stream methods because of the following:

- Buildings don't by necessity tell "lies"
- Such tools could be trans-cultural and therefore usable in other geographic areas
- There is no direct need for language translators in the field
- It has a certain appeal and seems reasonable to those in the architectural stream
- It fills a gap and allows validation and potential triangulation of research findings
- It enhances discussion within the teams
- Can rapidly produce base conclusions for critical reflection
- And hence (as mentioned earlier) the first tool of this work

QoL is defined by Wikipedia as "…an important concern in economics and political science. There are many components to well-being. A large part is standard of living, the amount of money and access to goods and services that a person has; these numbers are fairly easily measured. Others like freedom, happiness, art, environmental health, and innovation are far harder to measure. This has created an inevitable imbalance as programs and policies are created to fit the easily available economic numbers while ignoring the other measures that are very difficult to plan for or assess." (Wikipedia, 2011).

Despite there being 38 QoL tools the one used for this study called the DASS42 had the following significant advantages over the others (Potangaroa, 2006):

- The DASS42 does not need a before and after survey to draw relative comparisons. Most/all of the other QoL models have this requirement which means that any results, trends or tendencies are not known till after the "intervention". This is a crucial aspect for operational settings where identifying vulnerability, targeting assistance, informing programnes, comparison across programnes and early metrics for aid, and development situations are desired. The WHO QoL is a good example.
- It has been designed for use by non psycho-social professionals (such as architects and engineers). This is also crucial particularly where there is other psycho-social work underway. Moreover, it allows a more direct connection between the potential outcomes of the work rather than the outputs as identified as an issue earlier by Wikipedia.
- It deals with the ubiquitous non clinical context of QoL which is where de Botton was suggesting that "architectural happiness" exists.

- The questions are phenomena-logically based and are largely trans cultural. The questions are almost mundane and feel like the sort of questions friends might ask of each other. Some QoL tools are not so accessible.
- But more importantly do not generate expectations amongst the surveyed population. This particularly important in operational programmes where surveys can generate other unintended problems. For example questions aimed to identify whether vulnerabilities can convey the idea that if one were "vulnerable" that they could get more and potentially get it quicker.

The DASS42 questions are in appendix 1. It was developed at the University of New South Wales, in Sydney Australia (Lovibond, 1995). And is a "set of three self-report scales designed to measure the negative emotional states of depression, anxiety and stress" and was "constructed not merely as another set of scales to measure conventionally defined emotional states, but to further the process of defining, understanding, and measuring the ubiquitous and clinically significant emotional states usually described as depression, anxiety and stress" (DASS, 2006). The characteristics of high scorers on each DASS scale are as follows:

- Depression scale: self-disparaging, dispirited, gloomy, blue, convinced that life has no meaning or value, pessimistic about the future, unable to experience enjoyment or satisfaction, unable to become interested or involved, slow, lacking in initiative.
- Anxiety scale: apprehensive, panicky, trembly, shaky, aware of dryness of the mouth, breathing difficulties, pounding of the heart, sweatiness of the palms, worried about performance and possible loss of control.
- Stress scale: over-aroused, tense, unable to relax, touchy, easily upset, irritable, easily startled, nervy, jumpy, fidgety, and intolerant of interruption or delay.

The ability to characterize results and therefore not need a before and after study is because of the "severity" table feature of the DASS42 (refer to table 2 below). Consequently, results can be classified as normal, mild, moderate, severe and extremely severe that then allows both an individual and an aggregated classification. This aggregation means that comparison between different types of programnes such as health, housing and employment and also between different geographical zones is possible. This was not required for this study. This provided the second tool for this work.

Table 2: The DASS42 Severity Index Table (Devilly, 2005)

	Depression	**Anxiety**	**Stress**
Normal	0 – 9	0 – 7	**0 – 14**
Mild	10 – 13	8 – 9	**15 – 18**
Moderate	14 – 20	10 – 14	**19 – 25**
Severe	21 – 27	15 – 19	**26 – 33**
Extremely Severe	**28+**	**20+**	**34**

IV. SITE

The site selected for this study was Kampung Tunjungan. It is an informal settlement located in the CBD of Surabaya, Indonesia and is bounded by major roads and buildings. Its location means that residents have been able to find employment in these offices or by operating small businesses (often home based) such ready made food, barbers or tailors. The site was selected because of the previous contacts and work that ITS University had completed in the Kampung.

There are no parks or open public areas within the Kampung though residents often grow potted plants and flowers; lanes are narrow (typically 2.5 metres overall); and children by necessity play in the lanes. Houses built in the 1930'so seem to be better quality than those built later in the 1970's and the pressure to build has resulted in some houses not actually facing a lane. Some houses have a city supply water system, most do not and hence water purchase from shops or cartage from nearby wells is a constant requirement. Drainage is by gutters built in response to annual flooding of the Kampung and is usually maintained by each resident. Waste water is via these drains. House plots vary from 2.5x5 to 10x20 metres and some residents have constructed 2 storey homes. It is made up of 4 separate areas as shown in the map above.

V. METHODS

Training with both tools was given to the members of the 4 survey teams prior to their work in the field (one team for RW1 through 4). It consisted of PowerPoint presentations covering examples of the "10 Essential Patterns" taken from a visit 2 days prior to the training (and hence current). This was followed up by a walk through the Kampung where the Patterns procedure was used and discussed. Spatial areas associated with the houses were identified to standardize the survey approach and data collection. For example, the area immediately outside the house would need to be the start point for all teams. That is then connected to the porch or entry (where we were expecting a higher density of patterns), the lounge corridor and rooms and rear kitchen/bathroom areas

which would be subsequently examined. It was emphasized that several patterns could exist in one spatial area and in one architectural feature; and for example figure 3 below of a porch contains patterns 2, 3, 4, 5, 6, 7, 8, 9 and 10.

The other DASS42 survey tool had previously been translated into Bahasa by the Legal Department of Sykat Kuala University in Banda Aceh and checked by the Jesuit Brothers in Yojarkarta and used in over 10 different locations in Indonesia. Nonetheless, the version was review by the ITS team and some minor modifications made. The teams were then taken through the survey to ensure there was an agreement on what the questions meant and the process to be used.

Approximately 20 families were survey from each of the 4 districts (17 from RW1, 20 from RW2, 25 from RW3, 23 from RW4 hence 85 in total) during May 2011 and the results for the Patterns and the DASS42 were compiled using EXCEL spreadsheets. Those that had the higher QoL and the lower QoL were separated out and their patterns reviewed as the basis for the following results.

VI. FINDINGS

The DASS42 QoL results showed the following

- RW1: 4 reduced QoL factors involving 2 households
- RW2: 13 reduced QoL factors involving 7 households
- RW3: 0 reduced QoL factors
- RW4: 24 reduced QoL factors involving 16 households, 25 households in all.

Hence, RW3 would seem to have the best QoL followed by RW1, RW2 and finally RW4. The least QoL ranking for RW4 was consistent with the feeling within the survey teams and while it was not unexpected it was somehow still surprising.

The overall results from the Talk to the Buildings approach are shown below in table 3. The top half of those results suggest that the most commonly seen patterns were Pattern 1: Inhabiting site, Pattern 7: Composing with materials and Pattern 8: Sheltering roof. All areas, except RW3 (which had Pattern 5: Private edges common core and Pattern 6: The flow through rooms instead of 7 and 8) were essentially in agreement.

Table 3: Overall results from the Patterns Tool

Pattern	RW1	RW2	RW3	RW4	Total
1	45	52	66	65	228
2	40	50	63	61	214
3	36	47	62	54	199
4	38	48	65	65	216
5	37	46	69	65	217
6	42	46	68	54	210
7	45	56	65	72	238
8	43	54	60	73	230
9	37	46	64	57	204
10	34	42	61	58	195

Highest			Lowest			Average		
	RW 1	38		RW 1	13		RW 1	25.4
	RW 2	44		RW 2	11		RW 2	26.4
	RW 3	44		RW 3	17		RW 3	28.4
	RW 4	41		RW 4	19		RW 4	29.1
	Overall	44		Overall	11			

What then happens when these two tools are connected? Those with a "normal" classification for all 3 scales based on the Severity Table of the DASS42 were counted as "Happy" (following de Botton's terminology); those that anything else were treated as "Unhappy" and hence two data sets were created; one of "happy" people and another of "unhappy". For the 4 areas of RW1 to 4 there were 25 "Unhappy" households and 60 "Happy" ones. It should be again noted that all of RW3 were "Happy" and that RW4 had the lowest QoL and the most "Unhappy" households. The patterns data for these two groups were separated, analysed and any differences noted.

Firstly, it should be noted that the differences were numerically small. Nonetheless, it seems that more patterns were associated with a higher QoL (by 1.1 pattern differences based on average counts). This increases to 1.8 when the "Unhappy" data is compared to RW3 (where all households are "Happy"). Moreover, when one looks closely it seems that the ratio of Happy/Unhappy households equals the pattern difference. Consequently, an increasing ratio results in an increasing QoL which is notable firstly because it is not seemingly mentioned in the literature and secondly it has operational implications in that the addressing the next persons QoL greatly enhances the community response because of the non linear nature of the relationship (see table 4 and resulting graph below). Hence, "Happiness" seemingly breeds "Happiness" and more importantly that there does appear to be a connection between individual and community resilience given that the DASS42 is as suggested earlier (Pain et al, 2012). This was the unexpected result mentioned in the first line of the abstract which is now discussed further.

Table 4. Scale effects

	Ratio of Happy to Unhappy	Difference in Patterns
RW4	0.4	0.2

RW2	1.9	4.5
RW1	7.5	6.7
RW3	25.0	28.4
	(series 1 below)	(series 2 below)

VII. DISCUSSIONS

Certainly, the results from each tool were extremely useful and provided insights that would have otherwise not been realised.

But it was the results tabulated in table 4 (when the two tools were connected) that were perhaps stunning. What it demonstrated was that breaking data into those that are happy and not happy across other data opens up even further new findings. Secondly, it suggests that architecture (measured in terms of pattern density) has a direct correlation with the happiness/well being of an individual and a community. And that it is seemingly linear up to some threshold or "tipping point". That tipping point was a around a ratio of 7-8 of Happy to Unhappy. Below this ratio architectural inputs resulted in proportional happiness outputs, however when one is above the tipping point any further increase of architectural inputs results in significantly greater happiness outputs. Effectively, the community is resilient and self reliant and sustainable.

What does this mean for those field questions raised by Adam Pain and Simon Levine? (Pain et al, 2012). Firstly, the process can be readily used in the field and hence the resilience of affected populations regardless of whether it is a fast or slow onset can be identified. The word resilience is deliberately selected over capacity as resilience happens after the event while capacity is essentially established before. The well being process of the DASS42 does not tell you "why" but does tell you "who" and to "what degree"; previous work has also shown that bolting the DASS42 to other data bases can greatly assist in finding the "why" (Santosa et al, 2011), (Potangaroa et al, 2008). Thus, while we don't know exactly what to do we do have a way to measure whether we are heading in the right direction and moreover to compare the resilience gains for communities and individuals against a strategy of reaching the tipping point.

Moreover, this work suggests, and this is the proposition; that initially communities survive as individuals with individual resilience and it is only once the tipping point is reached that community resilience kicks in. The researchers would like to do further work in this area but are aware that this may be prevented by funding and hence this paper

VIII. CONCLUSION

Thus, we agree with the conference theme that resilience can only be achieved and sustained through thorough integration of both the built and the social environments. Planning a resilient city is a challenge to urban planning and all disciplines involved in general but strategic use of potential tipping points and the convergence of individual and community resilience that seemingly occur offers significant opportunities.

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21

Economic Development as Community Resilience Enhancement in Minapolis Coastal Settlement

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Abstract – *Indonesia as the largest archipelagic country in the world has its development focus on coastal areas through various program such as Minapolitan (fishtown). One of the Minapolitan area in East Java laid in Brondong regency with its reputation for the export-quality fish and its local people who mostly work as fishermen. The main and current activities in the minapolis settlement, the settlement that support minapolitan program, is community empowerment through fishing and fishery processing. For the last few years there is a decline in the amount of fishery production and an increase processing costs due to global climate change and the unsustainable exploitation behaviour in fishing and daily living in the settlements in Brondong. This phenomenon affects the stability and resiliency of the people especially who live in Brondong coastal settlements.*

This article aims to explain argumentations of a minapolitan economic development as a community resilient enhancement in Brondong coastal settlements in facing the climate change challenges and the impacts of such unsustainable exploitation. The findings of this assessment shows that the main factors affected the economic resilience in Brondong coastal settlements are the availability of social community and formal economic institution, institution capacity, the availability of fishery production centre, and social capacity. These factors then should be concerned and developed in the holistic coastal settlements concepts.

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Keywords*: Economic resilience, Coastal settlements community.*

I. INTODUCTION

1.1 Coastal Community Empowerment and Resilience

Coastal community empowerment is a systematic and continuous aware efforts to manage their potential resources or social capital optimally to develop social, economic, and politics of coastal community self-sufficiency (Kusnadi, 2009). Community empowerment becomes one of parameters to consider whether the development is sustainable in social-politics (Wiyana, 2004). Besides, Charles (2001) in Satria (2009) pointed out that sustainability behavior in community empowerment shown from every aspects suc as ecological, social-economic, community, and institution.

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Resilience defines as the ability of a system to maintain its structure and patterns of behaviour in the face of disturbance (Holling in Schoon, 2005), while Adger (2003) defines resilience as the ability to persist and the ability to adapt. Resilience has meaningful connection to vulnerability, which vulnerability itself generally has a human or society-centered perspective. This contrasts with a great deal of the early resilience literature which focuses more generally on eco-centric analyses. Geographers and natural scientists have quite often referred to vulnerability literature from within the study of natural hazards (Schoon, 2005). Resilience context in this article is referred to the ability of a coastal community system in the face of economic and climate change and disturbance through social and economic empowerment.

1.2 How does a community reputed as having strength in their social life?

Saefullah in Kusnadi (2006), in coastal zone development context or the application of development

intervention program, coastal community empowerment program and self-help behavior of fisherman is the most precious social-culture capital to support the aim of development realization. Those social-culture capitals may formed as these values: appreciating themselves and other people, social communication, teamwork, and mutual assistance, then become a relation of grouping communities that shown their existence. This is then well known as social capital. Coastal community empowerment activities aimed to enhance the quality of life and the social capacity from the poor in order to have self-help of social mobility and economic resources, and also a broad participation in community development for reaching social welfare that sustainable. Community self-help is totally needed to enhance their bargaining position in a zone development and utilize environment resources.

Located in the north coastal area of east java, Brondong coastal regency consists of four districts (Brondong, Sedayulawas, Labuhan, Lohgung). Since 2011, based on governor letter of consideration, Brondong has been selected as the central of Minapolitan area. Most of its supporting fishery facilities are totally complete and optimally used in daily life, such as Brondong Ocean Fishing Port and Fishery Market Spot. Due to large amount of fishery productions, Brondong has made Lamongan as the biggest fishery producer in East Java (Lamongan database of 2006). Not only the smallest area, but Brondong district also being the most rapid density in Brondong regency. It dominates for about 64% of density in Brondong regency (Brondong Regency Profile, 2011).

1.3 How does the coastal community empowerment in Brondong?

The number of coastal poverty in Brondong is shown in data of Pre Welfare Family of Brondong coastal zone in 2011 (Fig. 1). From the picture below, we can see that 39% of Pre Welfare Family is laid in Brondong coastal zone. This percentage is similar with 2,098 family or about 8,000 peoples. The economic condition of coastal community in Brondong is dominated by group of middle-low people that represented by groups of Pre Welfare, Welfare I (KS I), Welfare II (KS II) (Fig. 2.). More details based on BKKBN standard, the grouping of Welfare Family explained as below:

- Pre Welfare Family (Pra KS) are families who minimally haven’t full their basic needs yet, such as religious needs, meals, clothes, houses, and health. This group haven’t own a feasible housing so their mostly homeless.
- Welfare Family I (KS I) are families who able to minimally full their basic needs but unable full their social-psychologist needs, such as education, well-planned family, interactions in family, interaction in their living environment, and transportation.
- Welfare Family II (KS II) are families who in spite of their ability to full social-psychologist needs, they haven’t full their personal development yet, such as saving money and getting information.

Meanwhile there are some coastal community economic empowerment activities in Brondong, whether it’s formal (sponsored by government or non-government) or informal (initiate by the community themselves). Some of the formal coastal community economic empowerment which held in Brondong are:

- The established of Micro Finance Institution, named KUD “Mina Tani” Brondong, in 1980. This KUD manage 8 units of divisions: Loan and Saving, Health Care such as drugstore and policlinic, Sigaret Kretek Tangan (handmade cigarette production) which collaborate with PT. H.M. Sampoerna Tbk., Fishery Market Spot, Ice Block Factory, Cold Storage, Power Electricity Unit, and General Trading. KUD Mina Tani Brondong is one of the best East Java and Indonesia’s Cooperation (PUSKUD Jatim, 2012).
- Establishing Solar Packed Diesel for Fishermen (SPDN) Brondong, managed by Perum Prasarana Perikanan Samudra (PPS), for anticipating the effect of gasoline increasing price to the fishermen. However, this SPDN had through the limitation solar supply in 2011 (kabarbisnis.com, 2011). This caused the fishermen decreasing their sailing which affected to minimum fishery products.
- Establishing Micro Capital Service Unit (ULaMM) performed by PT. Permodalan Nasional Madani (Persero) for empowering Micro Business through Financing Service and Management Service. ULaMM gives loan services for business capital, mentoring, training, and monitoring to small and micro business for developing their business in order to increasing community welfare and preparing competitive small and micro entrepreneur.

Besides, informal coastal community economic empowerment activities which held is fishery processing such as dried fish and preservatives fish. Those activities owned and managed by the community of Brondong coastal settlement itself. The number of fishes around the coastal zone of Brondong has been declining over the last several years. It pursues the fishermen sail across the Java Sea towards the Sea of Kalimantan and Makassar. They exploit fish

there and often make conflicts with local fishermen. The fishing technologies used by Brondong fishermen are highly developed. Nearly 90% of them already used GPS as supporting tools in fishing. The large number of fishing capacity caused them using non-environmentally tools, such as Pukat Harimau or Troll. It had to be restricted by the local government, but some people modify it into Mini-troll or Payang Setan with more reachable price (only 3.5 million rupiahs). Besides causing the same harmful effects for coral reefs, Mini-troll also caused conflicts between the Brondong's and the Paciran's. Bubu tools, used by The Paciran's are often crushed away by Mini-troll of Brondong's.

II. METHODS

This article is a part of a qualitative research. The data collecting process and data analysis were conducted in qualitative approach. The data collecting process include in-depth interview which was initially conduct by a stakeholder analysis. Content analysis is then chosen to analyse a set of data collected from interviews.

III. FINDINGS

The most influence factors in optimizing coastal community economic empowerment to enhance resiliency in Brondong are mentioned below:

- The availability of social community
  Social community is the main factor in optimizing community economic empowerment because social-economic is the main problem in this area. Through this social economic, social interactions suggested to be developed by local community as a dense social capital. This cause the power of coastal development purely comes from the bottom (bottom-up planning). So far the availability of social communities is haven't strong enough in quality to support local community economic empowerment. It needs external support such as Non-Government Organization (NGO) or social activist who able waking up community aspirations and the existence of local people in coastal development.
- The availability of formal economic institution
  The formal economic institution is really helpful in securing economic resources given in community social life, considering the availability of KUD Mina Tani which is also important to manage the main assets such as National Fishing Port (PPN) that in a short term will have changed it levels into Ocean Fishing (International). Formal economic institution needs to adapt it perform with local social community there in order to avoid resistance from local people.
- Institution capacity
  Need to enhance the present governmental in facilitating and well understanding the local needs at the right point. To answer that, local institution supposed to identify their needs directly for reliable result. This need more supports both from Non-Government Organization and social activist to help local government in handling social-economics' problem.
- The availability of fishery production center
  Refer to Minapolitan concept which is applied in developing coastal zone of Brondong, the availability of fishery production center need to be concerned the needs and social activities there. Besides, fishery production center which us planned in this area also need to focused in environmental values.
- Social capacity
  The enhancement of social capacity of Brondong noticed to be supported by the several varieties of profession. Moreover, it also notice the chance that available from several varieties profession then it can support their local community economic independently and optimally.

IV. DISCUSSIONS

4.1. Content Analysis in Assessing Community Economic Empowerment Effect to Coastal Zone Development

Refers to deductive content analysis process above, the first stage is preparation (Figure 4). Start from selecting the unit of analysis which is 9 variables of the affect factors reached by literature review, selecting stakeholders by stakeholder analysis, and in-depth interviewing. Then it continued by transcription of conversation in interview. In the transcription, researcher also makes sense of the data by reading transcript in several times until familiar with the data.

The next stage is organizing. At this stage, matric developed based on data component. Then data gathering by content through highlighting text refers to variables which organized in matric. The highlighted is grouped into matric according stakeholder's row. From those following steps, concluded which variable's chosen mostly by each stakeholder.

The final stage of this process is resulting stage by abstraction. This stage results the most influence factors in optimizing coastal community economic empowerment in Brondong. Most of stakeholders agreed of all factors which asked. However, in determined all of those, there were some conditions that made them agreed to involve but unnecessary to

do. According to it, author made data reductions to several factors that noticed to be affected but not influenced enough to be the one. In the reduction of data, author also considering the existing condition of this area and the values of sustainable community development.

Organizing

- Developing analysis matrice
- Data gathering by content
- Grouping
- Categorization

Indicator	Variables	Stakeholder Groups				
		Lamongan Marine and Fisheries Department	Brondong Regency Institution	Brondong District Institution	Rukun Nelayan	Community Development Expert
Community participatory	Availability of micro business	Agree	Agree	Agree	Disagree	Agree
		T11.21, T11.23, T11.25, T11.26, T11.27, T11.28, T11.29, T11.30, T11.31, T11.48	T8.1, T8.2, T8.3, T8.8, T8.16	T9.1, T9.6, T9.37, T9.97	T9.27, T9.28, T9.30, T9.31, T9.38	T10.1, T10.2
Organizations	Availability of formal economic organization	Agree	Agree	Agree	Disagree	Agree
		T11.1, T11.2, T11.3, T11.5, T11.11, T11.13, T11.14, T11.51	T8.4, T8.5, T8.6	T9.10, T9.11, T9.12, T9.13, T9.20, T9.47, T9.89	T9.48, T9.49, T9.50, T9.51, T9.52, T9.53, T9.54, T9.55, T9.56	T10.3, T10.4, T10.5, T10.6
Social capital	Availability of social community	Agree	Agree	Agree	Agree	Agree
		T11.44, T11.45, T11.46, T11.47, T11.50	T8.7, T8.17, T8.18, T8.19, T8.20	T9.14, T9.15, T9.16, T9.17, T9.18, T9.19, T9.21, T9.22	T9.23, T9.24, T9.25	T10.7, T10.8, T10.9, T10.10, T10.11, T10.12, T10.13, T10.14, T10.15, T10.25, T10.26, T10.27, T10.38, T10.39, T10.40, T10.41, T10.42, T10.43
Corporation	Availability of fishery production center	Agree	Agree	Agree	Disagree	Agree
		T11.8, T11.32, T11.34, T11.43	T8.12, T8.13, T8.14, T8.15	T9.86	T9.82, T9.83, T9.84, T9.85, T9.87	T10.16, T10.17, T10.18, T10.19, T10.20
Coordination	Coastal zone management collaboration	Agree	Agree	Agree	Disagree	Agree
		T11.6, T11.7, T11.9, T11.17, T11.18, T11.41	T8.21, T8.22, T8.23, T8.35, T8.36, T8.37, T8.38, T8.39	T9.80	T9.78	T10.21, T10.22
Green Fisheries	Fishing technology	Agree	Agree	Agree	Agree	Agree
		T11.35, T11.36, T11.38, T11.53	T8.24, T8.40, T8.41	T9.95	T9.65, T9.66, T9.67, T9.68, T9.69, T9.70, T9.71, T9.72	T10.22, T10.24, T10.28
Economic welfare	Ability in access economic resources	Agree	Agree	Agree	Agree	Agree
		T11.19, T11.20, T11.22, T11.24, T11.33, T11.37, T11.39, T11.42, T11.49, T11.52, T11.54, T11.55	T8.9, T8.10, T8.11, T8.25, T8.29, T8.33, T8.34	T9.2, T9.3, T9.4, T9.5, T9.7, T9.8, T9.9, T9.33, T9.34, T9.36, T9.39, T9.40, T9.41, T9.57, T9.61, T9.63, T9.88, T9.96, T9.98	T9.35, T9.58, T9.59, T9.60, T9.64, T9.73, T9.74	T10.29
Social welfare	Social capacity	Agree	Agree	Agree	Disagree	Agree
		T11.16, T11.40	T8.26, T8.27, T8.30, T8.31, T8.32	T9.29, T9.32, T9.90, T9.91, T9.92, T9.93, T9.94	T9.75, T9.76, T9.77	T10.30, T10.31, T10.32, T10.33
Institutions	Institutional capacity	Agree	Agree	Agree	Disagree	Agree
		T11.10, T11.12, T11.15	T8.28	T9.45, T9.46, T9.81, T9.99, T9.100	T9.26, T9.42, T9.43, T9.44, T9.79	T10.23, T10.34, T10.35, T10.36, T10.37

*) Note :

Code: **"Tx.y"**

Tx = interview's transcript code attached in annex

y = citation/verbatim attached in annex

Fig. 1.
Variables Coding in Interview's Transcript
Source: Comparation between Interview's Transcript and Variables, 2013

V. CONCLUSIONS

Fishing overexploitation and environment degradation are two main problems that increase the vulnerability in Brondong coastal community. Describe in the discussions above, there are five factors found as the result of this article. These factors are the most influence in optimizing coastal community economic empowerment that affect the resilience in Brondong coastal community. They are as mention below:

- The availability of social community
- The availability of formal economic institution
- Institution capacity
- The availability of fishery production center
- Social capacity

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22 Climate Change Study on Coastal Settlements and Traditional Architecture in Madura Island, Indonesia

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Abstract – *Various studies on the phenomenon of global warming and climate change have been done. The results among other things are the rise of sea water levels and the change of air temperature. Such conditions would supposedly affect coastal settlements and its socio-economic as well as cultural future of the Madurese. The influence may also arise against existing Madurese traditional architecture. This study is aimed to understand the effects mentioned above.*
The method used in this study is a series of field observations and interviews conducted in four regencies in Madura Island. Changes observed are the natural phenomena associated with climate change, including the indication of sea level rise and preventive actions as well as the current condition of Madurese traditional architecture.
This paper is a preliminary result of the overall study. The indication of sea level rise are found in three observed areas. Meanwhile, the changes of Madurese traditional architecture found in this study are mainly due to densification process. All the results are expected to be the subject of further studies to gain the anticipation of possible negative impacts through adaptation efforts.

Keywords: *Climate change, coastal settlements, Madurese traditional architecture*

I. BACKGROUND

Madura Island is situated on the north of East Java, separated by Madura Straits. The majority of Madurese is devout Moslem society, while the main livelihood of Madurese is fishing. Fishermen settlements are scattered along the coast of this island. Other livelihoods are trader, tobacco farmer and salt maker.

Administratively, Madura Island consists of four regencies, from west to east respectively: Bangkalan, Sampang, Pamekasan and Sumenep.

The Madurese has its own traditional architecture that is slightly different compared to Javanese architecture. In order to boost Madurese socio-economic development, the Indonesian government built Suramadu Bridge, which connects Surabaya in East Java and Madura Island. This 5.438 meter long

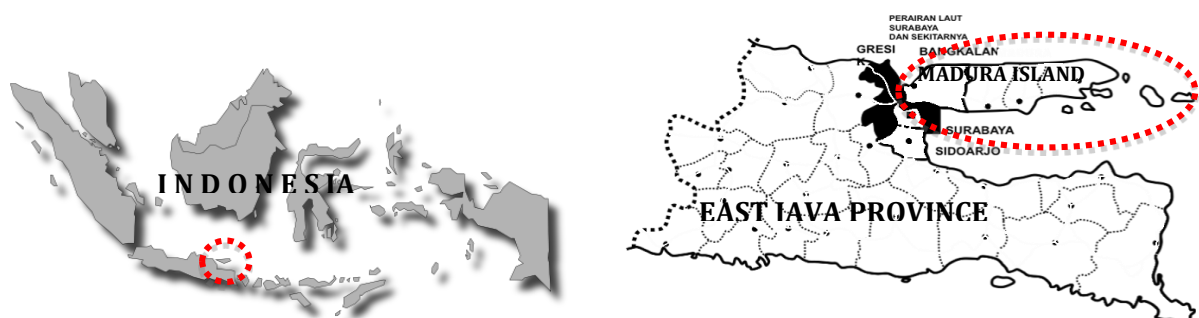



Figure 1: Indonesia and Madura Island

bridge is completed in 2009.

This study is conducted in relation to the climate change phenomenon. It is an observation process aimed if Madurese clearly comprehends such phenomenon and whether it affects Madurese built environment, especially its traditional architecture. Interviews were conducted with related stakeholders. The questions raised to the staff of local environmental authority office among other things are whether they aware and comprehend the climate changes basic issues and their implication in Madurese context. Other information obtained include the locations of the Madurese traditional architecture that still can be found within the regencies in Madurese island. The next step is visiting the sites and comparing them with the theory of traditional architecture based on existing literatures. Furthermore, information related to climate change research results are also used to analyze the existing conditions in the study areas.

II. THE LITERATURES AND FIELD FINDINGS

a. *The Madurese Architecture*

In 1986, Wiryoprawiro carried out a study on traditional architecture in Sumenep, Madura. Historically, Sumenep Kingdom existed in Madura Island in the past. This explains a variety of old kingdom buildings in Sumenep.

Tulistyantoro (2005) described his study on aspects and significance of the Madurese settlement. He explains that in the case of residential home extended family is adherent. The house is located on the North side, with *langgar* or *mushala* (a small mosque) located at the West end, while cattle sheds are located on the South. The layout of the kitchen was originally adjacent to the cattle sheds, but many kitchen layouts then shifted to the side or back of the house. In addition to cooking activities, the kitchen is also functioned as a place to store crops or agricultural products. The courtyard, which is formed and located in the middle of these buildings, is called *tanean*. A long courtyard is called *tanean lanjang*.

Dwelling is the main residence, usually only has one door toward the front. This building is a space to sleep with a full wall on four sides. In addition, there is an open porch with a half- wall that serves well as a sitting room or area to receive guests for women. Dwelling floor height is around 40 cm above the surrounding land. Ground floor material is earth, plaster or other materials such as terracotta. The doors are generally made of wood, and roof materials are palm leaves, thatch or tiles depending on the economic viability of its inhabitants. The form of floor plans, location of the main mast, and shape of the roof can distinguish building form. Based on the floor plan, the building is divided into *slodoran* and *sedana*. *Slodoran* consists of one room with two doors and a porch with one exit. *Sedana* has two rooms and two doors but only has one porch with one exit. Based on its main column, a building can be divided into *bangsal* and *pegun*. *Bangsal* has similar shape of Javanese *joglo* beheaded on either side, while *pegun* is shaped pyramid-like that has overhang on the front and rear part. Both types have the same structure of four main columns, but *bangsal* always has ridge with dragon tails shape.

From its form, roof can be differentiate into *pacenan, jadrih,* or *trompesan*. A roofed shed house is called *pacenan* (derived from the words *'pa-china-an'*). *Jadrih* is a roof type on a house with two ridges; while *trompesan* is a roof type that consists of three segments.

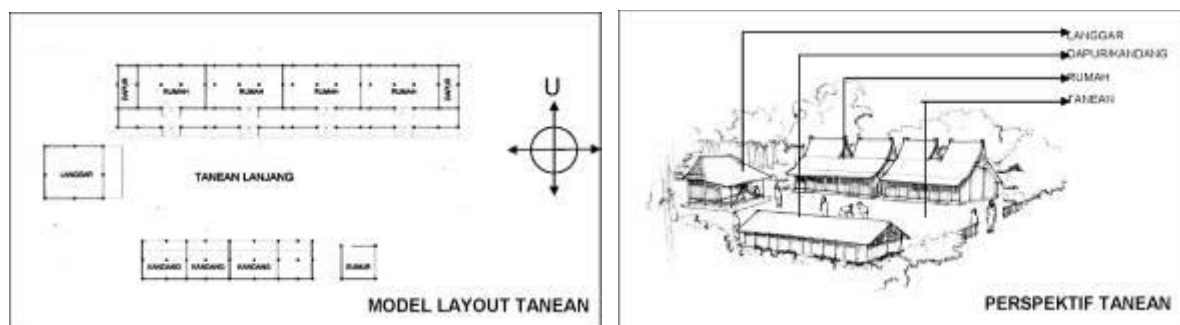
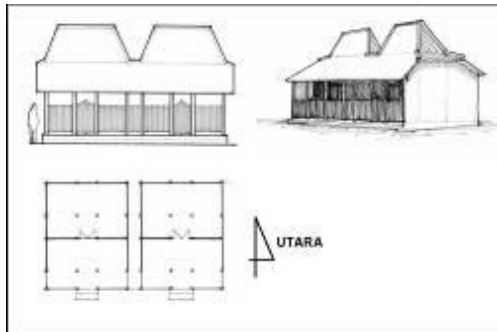
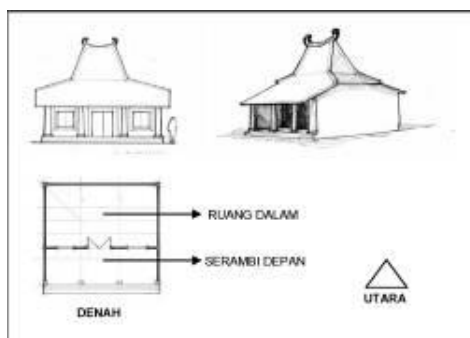
Figure 2: A courtyard is formed and situated among buildings within a Madurese settlement

a) Trompesan roof type

b) Pegun roof type

c) Pacenan roof type

Figure 3: Trompesan, pegun and pacenan roof types

b. The Climate Change factors

Climate change is a term refers to large changes in temperature, precipitation snow, or wind patterns lasting for decades or more. It is believed as real and urgent challenges that are affecting people and the environment worldwide. Climate change generates significant change on earth, including air and ocean temperatures rise, snow and ice melt, and the rise of sea levels. In this study, the observation on sea level rise is chosen as a method used in detecting the climate change at the study areas. Other climate change indicators indicated above require a long time to measure; especially air and ocean temperature rises, in order to acquire significant results. Declining in fish catches by the fishermen could also be resulted by the climate change phenomenon. However, several other factors have to be taken into account to get valid study results.

The study of Bappenas RI (Indonesian National Development Planning Agency) in 2010(b), pointed out that land temperature increase only 0.5^0 C in wet months (December to February) for the period between 1904-1994 (with Jakarta as the sample), while during the dry months (June to August) there is an increase of 1.5^0 C. In terms of sea level rise due to climate change in Indonesia, Bappenas RI (2010a) stated that the result in comparing the average of sea level during the period 2001 to 2008 and the period 1992 to 2000 shows a sea level rise between 2 - 12 cm with an average increase of 6 cm in a period of 7 years.

In architectural aspects, change in building material used or comfort in building interior might also be the results of the climate change. These cases also need several factors to be considered valid as climate change implication. In this study, change in building floor level or building relocation are due to the rise of sea levels.

c. The Field Findings

The interviews and discussions are carried out with related parties in four environment regencies (Bangkalan, Sampang, Pamekasan and Sumenep) offices in Madura Island. The results of these actions are mostly having none or barely related directly to climate change implication. The awareness of climate change consequences is still somewhat limited among staff in the environmental offices in all regencies in Madura Island.

There are four locations in northern coast of Madura and one in southern coast surveyed in this study. They are Sepulu and Tanjungbumi in northern Bangkalan regency, Ambunten and Pasongsongan in northern Sumenep regency, and Camplong in southern Sampang regency. The findings in those field survey areas are described below.

The observations, associated with the presence of Madurese traditional architecture conducted in Bangkalan regency, are barely found any group of buildings that form a complete residential area with its *tanean lanjang*. This fact is consistent with the study results conducted by Sharvina (2012) in Labang district, southern part of Bangkalan. She has

Figure 4: Madura Island

not found any Madurese settlement completed with tanean lanjang pattern there. However, some Madurese traditional buildings still exist in Sepulu, a small district at coastal area in northern part of Bangkalan.

(a)

(b)

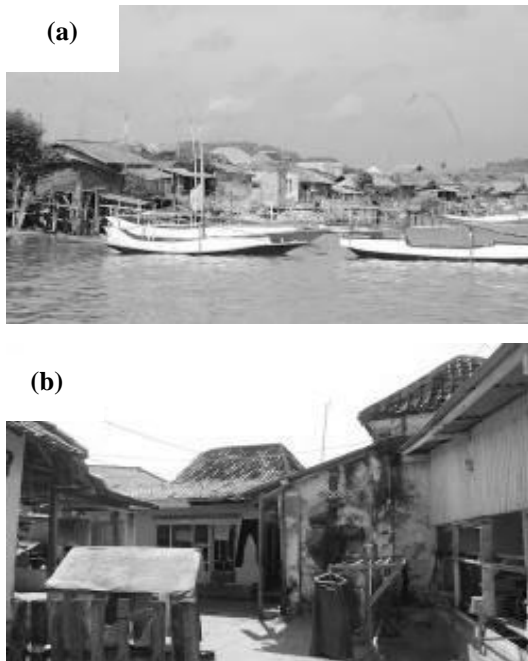



Figure 5: a) Fishermen village at Sepulu district; b) A traditional house found at Sepulu

From Figure 5b) above, clearly seen that one traditional house has been surrounded by other, relatively, new buildings. This densely populated village resulted on the need of more land to build their dwelling. This need is also shown in the following figure 6 a) & b) which showed an attempt to enlarge the coastal area through reclamation efforts.

(a)

(b)

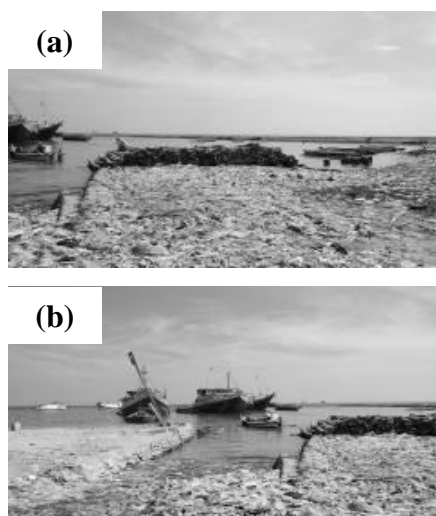



Figure 6 a) & b): A reclamation effort to get 'new' land for dwelling

On the other hand, it is clearly seen that tidal water level has increased in this area. This is demonstrated by the construction of embankments to protect the area from high waves. A broken house located right on the beach is also found. The information from the field stated that the inhabitants moved to another place that is considered as 'safer place' from the threat of rising sea level at this beach. These situations are shown in Figure 7 a), b) and c).

(a)

(b)

(c)

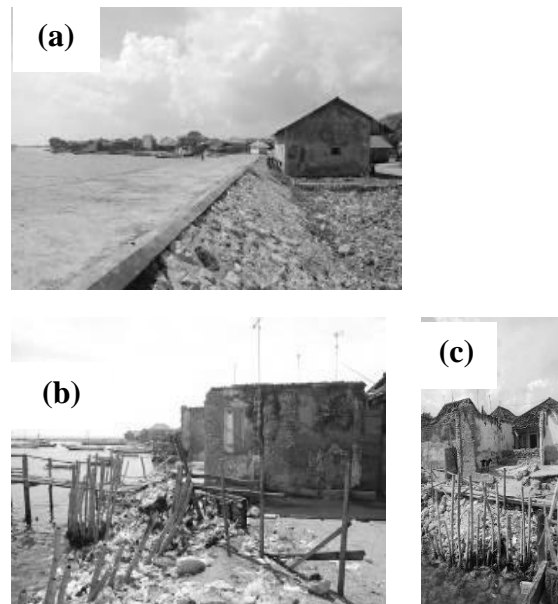



Figure 7a): The embankment, which gives protection from waves.
Figure 7b) & c): The broken & abandoned house

Furthermore, at this survey area, a wall was built with the purpose of a protection from the ocean tides. It is apparently made several times in different times. This can be indicated from the different materials used for that wall. This fact indicates the increase of tidal waves from time to time at this

Figure 8: A protection wall against tidal waves that was built in different phases

survey area.

In addition to the circumstances above, it has been found two buildings with Madurese traditional architecture character at this survey area. One building stands next to a new building. There is an open space in front of the second building. This space might be part of *tanean lanjang* in the past. (Figure 9a) and 9b)).

Figure 9a) & b): Two buildings with traditional architecture character at the surveyed area

In Camplong district, part of Sampang regency, at the southern coast of Madura Island, a protection wall was also found. However, it is not as high as the one in Sepulu, northern part of Bangkalan

Figure 10 a): Fishermen settlement at Camplong coast; b) The waves protection wall

regency. The coast settlement situation in Camplong and the waves protection wall can be seen in the

Figure 11 a) & b): Both figures show the existence of tanean lanjang as described above

following Figure 10.

In Camplong study area, some Madurese traditional architecture buildings are found. Some of these traditional buildings are situated at the same site. The existence of *tanean lanjang* still can be seen here, even though some buildings have changed their function. It is shown in the following Figure 11a) & b). Both figures were taken at the same location and from the opposite direction.

In Sumenep regency, two locations are chosen as the survey study areas, namely Ambunten and Pasongsongan. Both districts are situated at the northern coast of Madura Island. At Ambunten, local inhabitants describe the increase in sea level. They showed their graveyard that has been eroded underneath due to the reason above. They also explained that within the last five years, the level of tides is increased. They supported their story by showing the sign of previous water level tide.

Figure 12: Eroded graveyard land at Ambunten

At Pasongsongan district, the sea level rise was very clear. During the interview phase, a staff of Local Government Development Board explained that in Pasongsongan district, the Public Works Department was in the process of building a wall protection against the tidal waves. During the field survey, some parts of the protection wall were being prepared. Moulding of these reinforced concrete

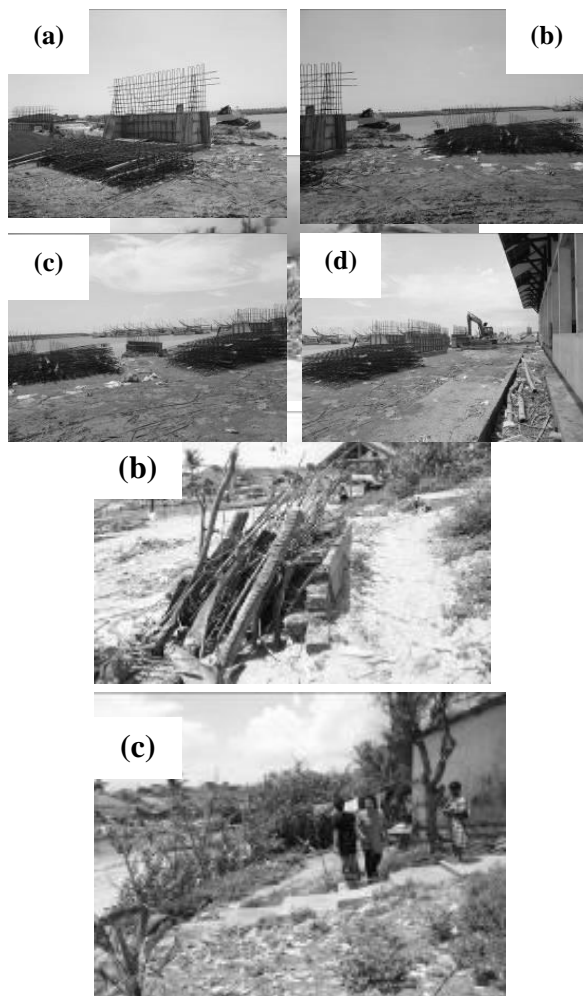



Figure 13 a), b) & c): All three figures above show the gradations of sea level rise points at Ambunten coast

walls were also in forming process. Some of the preparation works can be seen in the following figures.

III. CONCLUSION

From all the discussions described and figures presented above, some conclusions of this climate change study on coastal settlements and Madurese traditional architecture can be drawn as follows:

- The sea level rise is clear in all Madura coastal areas. This is evident with the construction of retaining walls in some places in the survey areas.
- The shifting of buildings to a higher location and the erosion happened on a cemetery site at the study areas also proved the sea level rise.
- The sea level rise on the northern coast of Madura, however, is higher than the south coast. The large area of Java Sea in compare

Figure 14 a), b), c) & d): The tidal waves retaining wall preparation process

  to Madura Straits might be the reason of these differences.
- Some Madurese traditional architecture buildings are still exist throughout the island. Meanwhile, the concept of *tanean lanjang* is barely found. It might be in the extinction process. The main reason of this process is the scarcity of land while the population is always increased over the years throughout the island.

In light of the findings above, some task actions that could be carried out by the government including:

- Provide periodic explanation to the public about a variety of negative consequences that may arise due to the phenomenon of climate change, and efforts to address them.
- Continue to take necessary actions against disasters caused by the sea level rise and protect the coastal settlements from the risen tidal waves.
- Preservation the remaining Madurese traditional architecture buildings and encourage Madurese society to rebuild the building compound with *tanean lanjang* concept. It might not be an easy process. Some government incentives in the form of property tax might be needed to preserve the traditional architecture treasures.

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Concept of Carrying Capacity: Challenges in Spatial Planning (Case Study of East Java Province, Indonesia)

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Abstrak – *East Java as a province which has strategic role at national scale has a real consequences of the population and natural resource consumption rising. The regional economic growth has not given significant contribution to the environmental sustainability issue. Hence, development should take carrying capacity into account in which population dwelled so that the concept of sustainability could be implemented.*

Masterplan as product of a spatial planning should consider various strategic issues which among of them are the environmental sustainability issue. Policies, plans and programs in masterplan should consider the environment carrying capacity through SEA (Strategic Environment Assessment). Using comparative analysis, SEA in masterplan of East Java Province has not fully described how the environmental capacity could accommodate spatial activities. The concept of carrying capacity through the implementation of SEA is not easily integrated in spatial planning, considering challenges faced are the difficulty of the integration and synchronization between SEA and spatial plan substance; studies focus on the environment which do not consider the social and economic objectives; and the longer formulation process on policies, plans, and programs of spatial plan

Peer-review under responsibility of the Cities International Seminar Committee.

Keyword *Carrying Capacity, SEA, Spatial plan, East java province.*

I. INTRODUCTION

There are two laws that expressly puts the values of the carrying capacity on development planning , namely Act No . 32 year 2009 on the Environmental Protection and Management and Act No. 26 Year 2007 on Spatial Planning . Environmental carrying capacity is a measure of the environmental ability to support humans life, other living beings, and the balance among both of it and a measure the environmental ability to absorb energy and / or other components that come incorporated into it (Rees and Wackernagel , 1996) . Environmental Carrying capacity aims to preserve the environmental functions and public safety , in the Act stated that any spatial planning document shall be based on strategic environmental assessment (Strategic Environmental Assessment) - is a series of systematic analysis, holistic, and participatory , to ensure that principles of sustainable development has become a basic and integrated on the development of an area and / or policies , plans and / or programs (Retnowati , 2013).

Economic growth in East Java province which has increased in recent years and shows that the performance of physical development and economic performance increasingly stretched . On the other hand , the activities of the construction and development of the region which is grow intensively still not consider the principles of sustainable development. While the development of the residents and their needs for access to resources is increasing, the declining of environmental conditions which is shown by the phenomenon of degradation and decline in the quantity and quality of natural resources and supporting means which become the needs of the

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population dwindling due to the limited existence . The result is some of the issues raised as the external issues of East Java Province, which are the increasing ratio of residents number in urban areas (migration) , the rapid development of the cities so that they appear more megacities, global warming issues, the restructuring of the core city functions resulting in urban spatial spillovers that occur agricultural land use changes in a large scale, technological developments which melt the physical boundaries between regions so that more and more cities have broad dimensions (globalization) . While the internal issues in East Java Province covers issues of population, the availability of infrastructure and socio-economic facilities, the gap of development concentration, food security, Sidoarjo mudflow, and the increasing conversion of forest and environmental damage that resulted in the escalation of disaster .

Thus , the growth conditions of East Java development is supposed to accommodate elements of the carrying capacity of the environment in accordance with the mandate of spatial policy and the environment both at the planning and implementation so that the carrying capacity of the environment could support the development continuously . But in reality the issue of environmental degradation cannot be avoided in East Java . To help toward improving the quality of spatial plans, the presence of a Strategic Environmental Assessment (SEA) is mandatory as a tool for spatial planning framework to address the environmental problem -based environmental carrying capacity. This paper aims to identify how the challenges of SEA implementation in spatial planning, particularly in East Java .

II. METH ODS

The method used in this research is descriptive comparative method. Comparative method is defined as the ratio between the substance of the research objectives with the concept or theory (Mill, 1872). In addition, a comparison technique is also the conclusion of two or more theories as a matter of clarification or clarifies a point (Ragin, 2005). In this research, comparative method was used to compare the concept of environmental capacity based on SEA instruments with the carrying capacity basic principles which is contained in the provincial spatial plan of East Java.

The first step is to conduct a literature review on the concept of carrying capacity through the instrument of SEA. Furthermore, a review of the product of spatial plans of East Java Province regarding plans, policies and programs that impact on the environment, as well as how the SEA implemented for the Spatial Plan East Java Province.

III. RESULTS AND DISCUSSION

3.1 Carrying Capacity Concept

Carrying capacity (carrying capacity) is defined as the maximum population that can be supported by a particular habitat indefinitely without damaging the productivity of the habitat permanently (Rees and Wackernagel , 1996). The definition of the concept of carrying capacity according to the Malthusian theory is contentious because it is close to understanding the context of the " war " with the human population so that an increase in the environmental carrying capacity leads to the suppression efforts of the human population . While Catton , 1986 (in Rees and Wackernagel , 1996) simply defines the environmental carrying capacity as the maximum carrying capacity continuously. That is, the human factors technology could pursue the use of natural resources remain within the limits of a maximum carrying capacity of the environment. Thus , the concept of Carrying Capacity is not solely related to how many maximum population, but instead related to capacity / maximum capacity entropy) environment that can be utilized by humans. So that in practice, the concept of carrying capacity is associated with the critical question of how productive land area required to support human needs (Rees, 1992 ; Rees and Wackernagel, 1994), hereinafter termed the palm of ecological (ecological footprint).

The concept of carrying capacity (Carrying Capacity) is naturally not a relationship that is fixed, static , and simple. This concept is closely related to technology, preferences, as well as the structure of production and consumption. This concept is also related to the interaction between the physical and biotic environment (Arrow et al . , 1995). Rees and Wackernagel, 1996 illustrates the concept of carrying capacity in city environments where the metabolism of a city analogous to human metabolism, where the city consumes natural resources from the environment and produce waste are then released into the environment again. So the concept of carrying capacity is closely related to two things (Khanna , 1999), ie the capacity support of natural resources (supportive capacity) of a city neighborhood with a capacity of waste/residues (assimilative capacity). Conceptually , the concept of carrying capacity is very clear but very difficult to estimate.

3.2 SEA (Strategic Environmental Assessment) as the Implementation of Carrying Capacity Concept
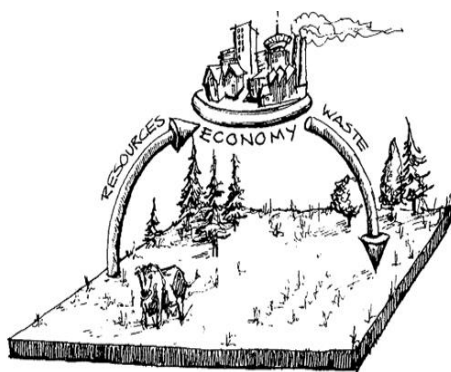
Fig. 1. Illustration of City Metabolism Regarding The Concept of Carrying

The concept of carrying capacity is to be implemented through development policies oriented at carrying capacity of the environment. SEA is an instrument developed for the purpose of management and environmental protection in Indonesia. SEA aims to assist in managing and protecting the environment and promoting sustainabilit. SEA is defined as follows :

"SEA is a systematic process for evaluating the environmental Consequences of proposed policy , plan or program initiatives in order to Ensure they are fully included and appropriately addressed at the earliest stage of NAMAs decision making on par with economic and social considerations."(Sadler and Verheem, 1996 in Therivel, 2004.)

Another definition of the SEA should be also related to the principle of policy integration and sustainable development plans and programs in accordance with the environmental carrying capacity (Deputy Sustainable Environment, Indonesia Ministry of Environment, 2007). Some principles of SEA are (Therivel , 2004) :

- SEA is a tool to increase the strategic action.
- SEA should promote the participation of other stakeholders in the decision-making process.
- SEA should focus on environmental constraints /key sustainability, thresholds and limits on the appropriate level of plan-making.
- SEA should help identify the best options for strategic action.
- SEA should aim to minimize the negative impacts, optimize positive, and compensate for the loss of valuable benefits.
- The SEA must ensure that the strategic actions do not exceed the limits of the impact that permanent damage may occur

Spatial planning in Indonesia produces planning products containing formal spatial policies, plans and programs. Policies , plans and programs are aimed to create a better spatial planning quality. However, environmental issues are still going on and the indication of a decrease in environmental quality and carrying capacity. Therefore, in the preparation of spatial planning should take the environmental carrying capacity into account through the SEA (Government Regulation No. 15 of 2010 on the Implementation of Spatial Planning). SEA approach to spatial planning in Indonesia is divided into four, namely:

- SEA as a basic framework of the EIA (Environmental Impact Assessment)
  This approach has a procedure similar to the EIA (Environmental Impact Assessment) to examine the effects and impacts of spatial plans posed to environmental quality.
- SEA studies assessing environmental sustainability (Environmental Appraisal)
  This approach did a review of the policies contained in the Spatial planning with the specific environmental point of view.
- SEA as an integrated assessment / environmental sustainability assessment (Integrated Assessment / Sustainability Appraisal)
  This approach did a review of the policies contained in the spatial plan with a holistic perspective , from the standpoint of social, economic and environmental.
- SEA as an approach to sustainable natural resource management (Sustainable Natural Resource Management).
  This approach was applied by emphasizing natural resource considerations as substance in Spatial plan, and as an affirmation of spatial plan as the reference rule of resource utilization and protection of natural reserves.

SEA has a different role according to the level of the spatial plan product hierarchy. At the level of the provincial spatial plan, the SEA is transformative, which means that the results of the SEA works to improve the quality and substance of the Spatial Plan formulation process, as well as facilitating the process of decision making in the planning process in order to balance environmental objectives with social and economic objectives. Studies on SEA minimum load:

- the carrying capacity and environmental capacity for development
- An assessment of environmental impacts and risks
- Performance of service / ecosystem services
- Efficient use of natural resources
- The level of vulnerability and adaptive capacity to climate change
- The level of resistance and the potential for biodiversity

3.3 SEA in East Java Provincial Spatial Plan Year 2011-2031

The East Java Provincial Spatial Plan 2011-2031 compiled to provide an operational reference for the sectoral development implementation. It is designed by considering all aspects including environmental capacity in order to achieve harmony between the natural environment and artificial environment. East Java economic growth which increasing continuously need to be contained in the spatial plan so that in the document said that the development of the East Java Province is directed to support and realize the commercial services sector to deal with the dynamics of globalization and free trade, so as to bring the various sectors in East Java become more valuable and encouraging regional economic growth.

On the other hand, the growth of the region should not neglect the aspects of sustainable development, which directly or indirectly will remain a major bearing capacity of all activities. Sustainable development is a conscious and planned effort that combines aspects of environmental, social, and economic to the development strategies to ensure the integrity of the environment as well as safety, capability, welfare, and quality of life of the present generation and future generations.

Therefore , this document is drawn up through a series of stages and assessment to the condition of East Java Province plans so that drawn up plan can accommodate all aspects and full of harmony. Some of the strategic issues that underlie the preparation of spatial planning documents include:

- The issue of land capability and land conversion
- The issue of economic inequality, infrastructure and human resources
- The issue of natural disasters and vulnerability
- Lapindo Sidoarjo mud disaster issues and economic implications
- The issue of conversion of protected forest and paddy farming
- The issue of disintegration agricultural sectors and not optimal increase in value -added agricultural production.
- The issue of urban growth that leads to urban sprawl
- The issue of food security
- The issue of the development of strategic infrastructure such as transportation, energy and telecommunications.

In relation to the extent to which the concept of carrying capacity was adopted in The East Java province spatial plan is then necessary to review how the framework of SEA is implemented in the preparation of policies, plans, and programs. Policies,plans and programs in East Java province studied their effects on the environment are as follows:

Table 1. Effects of Policy, Plan Program of The East Java Provincial Spatial Plan to The Environment

No.	Policies	Plans and Programs	Effects
1.	Controlling City System Policy	The development of urban centers which hierarchical one to another and are associated with rural systems create a system that supports the growth and spread of various activities	• The negative impact is expected to come from the effects of rapid urban development on agricultural land availability, environmental disturbances and the like. It is given, that in urban centers has meant agricultural land reserve wetland which is high enough. The development of new urban centers which is close to forests and conservation feared the emerge of conflicting land use.
2.	Regional Infrastructure Policy	Southern Cross Road Network Development as the development plan of the National Strategic Road Network (still not connected yet)	The opening of the new road will affect the trend of the development of aquaculture activities, especially in protected areas, forests and conservation through JLS. The opening of roads and improvement of the quality of the road and its grade at country area will also trigger a land use change of agricultural land into non-agricultural land so as to reduce the agricultural land reserve (food security).
		Expansion of Tanjung Peark Port due to its current capacity already saturated by	Adding the burden of the environment (land) which already exist, such as, floods etc. Susceptible to environmental conditions such as the disruption of

the increasing demand and regional economic growth	port activities that will be developed

Source: Adopted from SEA Proceeding, 2011

The policies, plans, and programs effect study contained in the Provincial Spatial Plan towards

environmental strategy just had been conducted on issues related to disparities and development facilities and regional infrastructure. SEA in this context is only executed on a qualitative study on how much the influence of policies plans and programs will be developed will affect to the environment. However, the results of this study may not fully represent that space utilization is well within the carrying capacity of East Java province. Therefore, SEA to support environmental capacity of East Java region needs to be internalized in spatial plan product.

The internalization of SEA in East Java spatial plan can be made through integration of SEA with Spatial plan content. However, this integration process becomes not easy because the analysis stage in the SEA is difficult to be synchronized with the formulation stage of policies, plans and programs in East Java spatial plan. In the formulation of policies, plans and programs of East Java spatial plan have considered several principles which is related to environmental sustainability, such as efforts related to conservation of protected areas. SEA towards East Java spatial plan is still not done yet thoroughly and systematically on various strategic issues.

IV. CONCLUSION

Management efforts and environmental protection done through one of the study on carrying capacity. SEA as one instrument of carrying capacity should be included in spatial plan. SEA in spatial plan is transformative which give improved quality on the substance formulation process, and can facilitate decision-making in the planning process in order to balance between environmental, economic, and social objectives. However , SEA which contains environmental carrying capacity study having a procedures and steps which are difficult to be implemented in the spatial planning process.

Some of the challenges to implement the SEA into spatial plan are :

- Difficulties on the integration and synchronization of SEA substance with the spatial plan substance.
- SEA focus on environmental viewpoint which do not accommodate the social and economic goals such as on policies, plans and programs in Spatial plan.
- SEA provide a thorough environmental assessment over territorial strategic issues that impact on the longer formulation process for policies, plans, and programs of spatial plan.

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24

Identification of Indicators Influencing Sustainability of Minapolitan Area in Lamongan Regency

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Abstrak – *Lamongan is known as one of minapolitan area in East Java Province. The concept of minapolitan was introduced in order to overcome the equal development in small cities that has potential in fisheries sector. The minapolitan areas in Lamongan are located in Brondong and Paciran District. The efforts to foster the development of minapolitan area are still fostered by the central government as well as the local government in the context of sustainable development. The method used to identify the indicators influencing the sustainability of minapolitan area in Lamongan Regency is Delphi technique. The results showed that the selected indicators are categorized into three aspects, i.e. social, economy and environment.*

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Keyword: *Carrying Capacity, SEA, Spatial plan, East java province.*

I. INTRODUCTION

The concept of minapolitan was designed to develop small and self-reliance cities as well as to slow down urbanization to large cities in Indonesia. Minapolitan is a cycle of dynamic process that involves the role of integrated multi sectors to realize a small town with sustainable fisheries-based (Wiadnya, 2011). It is understood that the development of minapolitan area has intention to improve the social and economy aspects of the community, without neglecting environment aspect.

Based on the Decree of the Marine Minister No. 32/Men/2010 on Minapolitan Zone Determination, Lamongan was designated as one of the 197 districts Minapolitan Region. The decree is considered appropriate because Lamongan Regency is leading in the fisheries sector. Moreover, Lamongan is the largest producer of fisheries in East Java Province (East Java in Figures, 2012). Lamongan has 2 minapolitan areas, those are Brondong as the fishery port and Paciran District as the hinterland. The development of minapolitan area in Lamongan has been 4 years since it was set as one of minapolitan areas in East Java Province. However, the sustainability of the minapolitan area is not yet known. The sustainability is important to be evaluated in order to achieve the sustainable minapolitan area. This study has intention in determining the suitable indicators influencing the minapolitan area in Lamongan Regency. This article is part of a study about sustainability development in minapolitan area of Brondong, Lamongan Regency.

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II. SUSTAINABLE MINAPOLITAN REGION

2.1 Purpose and Characteristic of Minapolitan Region

The purposes of Minapolitan area development as the concept of the Blue Revolution are 1) to increase production, productivity, and quality of the marine commodity, fisheries cultivation and dairy products, 2) to develop a system mina-business, 3) to develop a centre of economic growth in Minapolitan region and 4) to increase revenue and welfare in a fair and equitable society, particularly fishermen, fish farmers, and fish cultivators (Agropolitan and Minapolitan, 2012). In addition, Minapolitan has specific characteristics, such as 1) has production centres,

processing, marketing and other business activities, such as services and trade, 2) has the infrastructure to support the economic activity, 3) accommodate and employ human resources in Minapolitan area and the surrounding area, and 4) has a positive impact to the economy in the surrounding area.

2.2 Concept of Sustainable Development

Sustainable development is broadly known as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (United Nations, 1987). It has been realized that economic growth alone is not enough: the economic, social and environmental aspects of any actions are interconnected (Strange and Bayley, 2008). Moreover, the goals of economic and social development must be defined in terms of sustainability in all countries - developed or developing, market-oriented or centrally planned. Interpretations will vary, but must share certain general features and must flow from a consensus on the basic concept of sustainable development. Sustainable development is seen as three components, i.e. 1) a conceptual framework: a way of changing the predominant world view to one that is more holistic and balanced, 2) a process: a way of applying the principles of integration – across space and time – to all decisions, and 3) an end goal: identifying and fixing the specific problems of resource depletion, health care, social exclusion, poverty, unemployment, etc. (Strange and Bayley, 2008).

2.3 Indicators of Sustainable Minapolitan Region

In order to obtain indicators of sustainable development of minapolitan region, several literatures have been reviewed. The literatures are Indicators of Sustainable Development (United Nations, 2007), Measuring Coastal Sustainability (2012), Integrated Management of Coastal and Sea Area (Dahuri, 2004), Coastal Planning and Management (Kay and Adler, 2005). In 2013, the study on Concept of Minapolis Settlement Development has been completed (Rahmawati et.al, 2013). This study proposed concepts that are related to the three aspects of sustainable development, i.e. social, economy and environment. The previous resources were used to formulate the initial indicators that will be distributed to the corresponding respondents. The indicators used in this research are categorized into three aspects that should be taken into account in the context of sustainable development. The indicators for social aspects are level of community education, percentage of community with access to primary health services, proportion of under welfare population road condition, proportion of community with access to electricity, proportion of community with access to clean water, government support and community support. In the economic aspect, the related indicators are volume and value of fisheries production, contribution of fisheries sector to the GDP, ratio of working community, number of unemployment, number of mina-business units, number of supporting facilities to mina-business and number of people working on mina-business sector. The indicators to determine the environment aspect are proportion of land use, number of community live in coastal area, proportion of fish stocks within safe biological limit and waste disposal method.

III. METHODOLOGY

The type of this research is a kind of qualitative research. The method used to determine the indicators influencing the sustainability of the Minapolitan Areas in Brondong and Paciran is Delphi technique. The Delphi concept was originally developed in early 1950's in the spinoffs of defence research (Dalkey and Helmer, 1963). The objective of the original study was to obtain the most reliable consensus of opinion of a group of experts, by a series of intensive questionnaires interspersed with controlled opinion feedback (Linston and Turoff, 2002).

The respondents of the Delphi technique were selected by using purposive sampling. There are three groups of respondents, those are governments, fishermen entrepreneurs and fishermen community. For the purpose of purposive sampling, a set of criteria to select the respondents was formulated for each group of respondents. The Delphi process involves several steps, such as exploration and iteration.

IV. RESULTS AND DISCUSSIONS

The analysis to determine the indicators influencing the sustainability of Minapolitan Area in Lamongan Regency started with building a series of questionnaires. The result of exploration process is shown in table below. At this step, the respondents expressed their agreement and disagreement. In this case, the respondents were asked to state their rationale concerning their answers.

Criteria	Indicators	Respondents					
		R1	R1	R3	R4	R5	R6
Education	Level of community education	√	√	√	X	√	√
Health	Percentage of community with access to primary health services	X	√	√	√	√	√
Poverty	Proportion of under welfare population	√	√	√	√	√	√
Infrastructure availability	Road condition	√	√	√	√	√	√
	Proportion of community with access to electricity	√	√	√	√	√	√
	Proportion of community with access to clean water	√	√	√	√	√	√
Economic performance	Volume and value of fisheries production	√	√	√	√	√	√
	Contribution of fisheries sector to the GDP	√	√	√	√	√	√
Labour	Ratio of working community	√	√	√	√	√	√
	Number of unemployment	√	√	√	√	√	√
Land use	Proportion of land use	√	√	√	√	√	√
Coastal area	Number of community live in coastal area	√	√	√	X	√	√
Fishery	Proportion of fish stocks within safe biological limit	√	√	√	√	√	√
Waste disposal	Waste disposal method	√	√	√	√	√	√
Mina-business	Number of mina-business units	√	√	√	√	√	√
	Number of supporting facilities to mina-business	√	√	√	√	√	√
	Number of people working on mina-business sector	X	√	√	√	√	√

Note: √ : Agree
X : Disagree

Table 1. Delphi Exploration Result – Step 1

From the exploration process, it is known that the respondents have not yet reached a consensus on the indicators that are considered useful in the sustainable development of minapolitan area. In addition, there are two new indicators obtained from the exploration process. Those indicators are shown in the Table 2 below.

The second step after the exploration process is iteration process. In this step, the respondents received a questionnaire that includes the indicators and judgments summarized by the researcher in the previous step. The respondents were then asked to revise their judgments or to specify the reasons for remaining outside the consensus. This step could give the respondents a chance to make further clarification of both the information and judgment of the relative importance of the items. The result of iteration process is shown in the table 3 below. After the first iteration,

Indicators	Note
Level of community education	Not reach a consensus yet
Percentage of community with access to primary health services	
Number of community live in coastal area	
Number of people working on mina-business sector	
Government support	New Indicators
Community support	

Table 2. Indicators that need to be iterated

Criteria	Indicators	Respondents					
		R1	R1	R3	R4	R5	R6
Education	Level of community education	√	√	√	√	√	√
Health	Percentage of community with access to primary health services	√	√	√	√	√	√
Coastal area	Number of community live in coastal area	√	√	√	√	√	√
Mina-business	Number of people working on mina-business sector	√	√	√	√	√	√
(New indicators)	Government support	√	√	√	√	√	√
	Community support	√	√	√	√	√	√

Table 3. Iteration Process

the consensus was achieved. The two new indicators have been agreed by the respondents as well. The selected indicators influencing the sustainability of minapolitan area in Lamongan Regency identified through the Delphi technique are shown in table below.

Aspects	Selected Indicators
Social Aspect	Level of community education
	Percentage of community with access to primary health services
	Proportion of under welfare population
	Road condition
	Proportion of community with access to electricity
	Proportion of community with access to clean water
	Government support
	Community support
Economic Aspect	Volume and value of fisheries production
	Contribution of fisheries sector to the GDP
	Ratio of working community
	Number of unemployment
	Number of mina-business units
	Number of supporting facilities to mina-business
	Number of people working on mina-business sector
Environment Aspect	Proportion of land use
	Number of community live in coastal area
	Proportion of fish stocks within safe biological limit
	Waste disposal method

Table 4. Selected Indicators Influencing the Sustainability of Minapolitan Area in Lamongan Regency

V. CONCLUSION

Sustainable development is not only a concept, but it is also a dynamic process and an end goal. Therefore the government should consider implementing this in all kinds of development. The idea to foster the development in small and medium cities should be also followed by the awareness that development must consider the environment aspect, not only the economy and social aspects. This research concludes that the indicators that influence the sustainable development in minapolitan area in Lamongan are categorized into three aspects, i.e. economy, social and environment. The indicators for social aspects are level of community education, percentage of community with access to primary health services, proportion of under welfare population road condition, proportion of community with access to electricity, proportion of community with access to clean water, government support and community support. In the economic aspect, the related indicators are volume and value of fisheries production, contribution of fisheries sector to the GDP, ratio of working community, number of unemployment, number of mina-business units, number of supporting facilities to mina-business and number of people working on mina-business sector. The indicators to determine the environment aspect are proportion of land use, number of community live in coastal area, proportion of fish stocks within safe biological limit and waste disposal method.

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Keputusan Menteri Kelautan dan Perikanan Republik Indonesia No. 32/Men/2010 tentang Penetapan Kawasan Minapolitan

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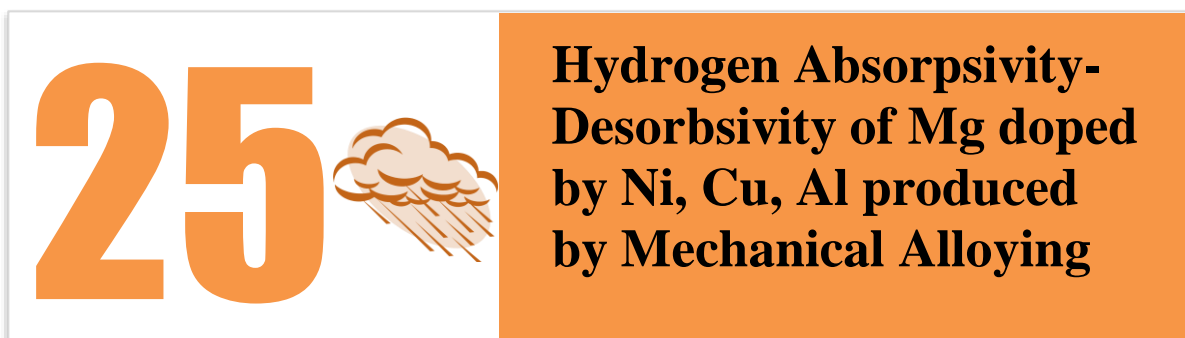
25 Hydrogen Absorpsivity-Desorbsivity of Mg doped by Ni, Cu, Al produced by Mechanical Alloying

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Abstrak – *Mg, in the form of MgH_2, is one kinds of materials widely used as hydrogen storage materials. Absorption and desorption properties of hydrogen which comes from metal hydride depend on materials itself, addition of elements, as well as manufacturing method. In this research, Mg as hydrogen storage were prepared by mechanical alloying with Ni, Cu, and Al as element addition and variation milling time for 10, 20 and 30 hours. Some morphological analyses (XRD, SEM) were done to observe phase transformation. Absorption and desorption properties characterization were employed by DSC and hydrogenation tests. The improvement in milling time decreased particle size, therefore enhanced wt% of absorbed hydrogen and decrease onset desorption temperature. However, the excessive of agglomeration and cold welding on mechanical alloying process resulted in bigger particle size. Alloying elements, Al and Cu, served as catalyst, while Ni acted as alloying which reacted with hydrogen. Mg10wt%Al with 20 hours milling time at hydrogenation temperature 250°C, 3 atm pressure, and 1 hour holding time resulted in the highest weight percent of H_2 (0.38%wt). However,*
Mg10wt%Al with 30 hours milling time had the lowest onset temperature, 341.49^0C
Keyword: *Absorption, desorption, hydrogen storage materials, mechanical alloying, Mg.*

I. INTRODUCTION

The large potential of hydrogen as an alternative energy for transportation have several advantages such as their naturally abundance, light, high combustion producible, reproducible, and zero emission as well as environmentally friendly. The medium to store hydrogen can be gas, liquid, and solid [1]. The formation of solid-state storage which is more safety instead of gas or liquid is due to the presence of metal hydrid that can be comes from metals or alloys. In addition, metal hydrid has higher level solid-state of hydrogen storage ($6.5 atoms/cm^3$ for MgH_2) as compared to gas ($0.99 atoms/cm^3$) as well as liquid ($4.2 atoms/cm^3$). Hence, metal hydride is a safety and efficient hydrogen storage to be applied in transportation on-board [2].

Furthermore, many researchers concern on Magnesium as hydrogen storage because of its high capacity to store (*ca*. 7.6 wt.%) and low cost ($3.5 per kg Mg). Nevertheless, thermodynamically result properties of magnesium hydride (MgH_2) show that high temperature needed during hydrogen absorption/desorption. These high temperatures are due to the high thermodynamic stability of MgH_2 which result in high desorption enthalpy as well (*ca*. -74 kJ/mol H_2). Moreover, it consumes times to alter magnesium into magnesium hydride [2]. There are two methods which have been used by many researchers to improve the characterization of magnesium hydride. The first method is addition of catalyst, for instance some metallic elements such as Ni, Mn, Fe, Cu, or Al even Oxide metal [3]. These elements change surface properties, microstructure, and grain size by mechanical alloying. In this way, the storage capacity will slightly decrease, in other words, these metals act as a gate for hydrogen in surface of hydride. The second method is modification of thermodynamic properties by alloying based on Mg [3].

In addition to those methods, improvement in absorption/desorption hydrogen properties in magnesium or alloy which based on magnesium can be conducted by synthesis method, mechanical alloying. Moreover, this method has two advantages; first, facilitate formation of alloys and hydrides; second, obtaining Mg based on micro even nanocrystallin by dislocation and special defects with high energy to bind hydrogen [4]. Finally, this research will be conducted on synthesize of hydrogen storage materials using Mg as material base with addition of Ni, Cu, and Al by mechanical alloying method.

II. MATERIALS AND METHOD

Powders supplied by Merck, Mg with 98.5 of purity and Al, Cu, and Ni with 90, 99.7, and 99.5 of purity, respectively. Mechanical alloying process is conducted by Ball mill Retsch PM400, with the ratio of weight and powder 10:1. This process occurs under argon atmosphere with variation milling time 10, 20, and 30 hours with the rate 400 rpm. X-Ray Diffraction (XRD) in the range 5-90 (2Θ) (step size = 0.0167°, scanning rate = 10.000-89.9968 s/step) by using filtered Cu Kα radiation (λ = 1.54 Å) and Scanning Electron Microscopy (SEM) were carried out to indentify phase transformation of compound formed and observe morphological structure of powder after mechanical alloying process. Differential scanning calorimeter (DSC) and hydrogenation test were performed to evaluate their absorption and adsorption properties. DSC test is conducted under nitrogen atmosphere at a scanning rate of 10°C/min from 25^{0}C to 500°C, while hydrogenation test was carried out for 1 gr of hydrogenated sample in vial with 47 ml of volume and 3 atm of hydrogen pressure at 250°C for 1 hour.

III. RESULT AND DISCUSSION

3.1 Powder Characterization

Microstructures of Mg, Ni, Al and Cu powders were analyzed by SEM analysis. This result can be analyzed to evaluate the difference of alloy product which comes from addition of elements or mechanical alloying.

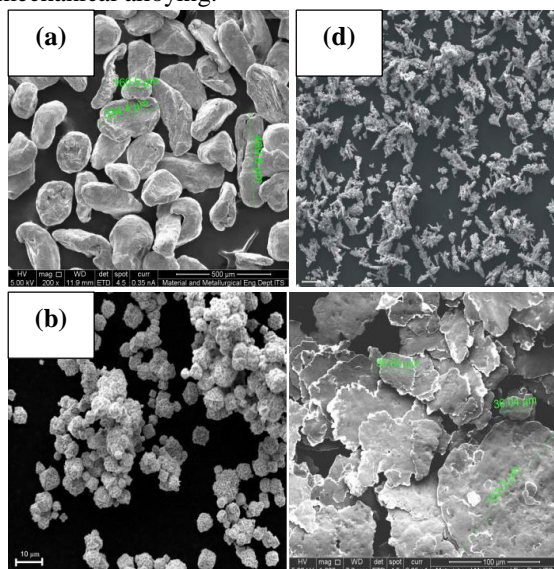



Fig 1. SEM pattern of (a) Mg, (b) Ni, (c) Al, (d) Cu powder

Fig. 1 shows that Mg powders are in the shape of angular with 100-300 µm of particle size, while sponge (2-10 µm), flat (30-160 µm) and dendrite (20-60 µm) for Ni, Al and Cu, respectively. In this case, flat particles (i.e. Al) and small particle sizes of Ni and Cu give advantages in mechanical alloying process due to high surface area of Mg with additional elements.

3.2 X-Ray Diffraction (XRD)

XRD analyses were further performed for mechanical alloying product (Mg10wt%Cu, Mg10wt%Al, and Mg10wt%Ni with variation time of milling 10, 20, and 30 hours) to evaluate new formed phase. In agreement with previous results [4, 5], New formed phase for Mg10wt%Al are Mg, Al, and $Mg_{17}Al_{12}$; Mg10wt%Cu are Mg, Cu, dan Mg_2Cu; while for Mg10wt%Ni are Mg, Ni, dan Mg_2Ni. This results show that alloying between Mg and Al, Cu, or Ni have been formed since 10 hours milling time. In this case, some decreases in the peak intensity of Mg, $Mg_{17}Al_{12}$, Mg_2Cu, as well as Mg_2Ni is detected (see fig. 2), suggesting during mechanical alloying process occur atom diffusion into Mg particles. In addition, improvement in milling time result in higher atom diffusion, therefore it decreases the intensity of Mg.

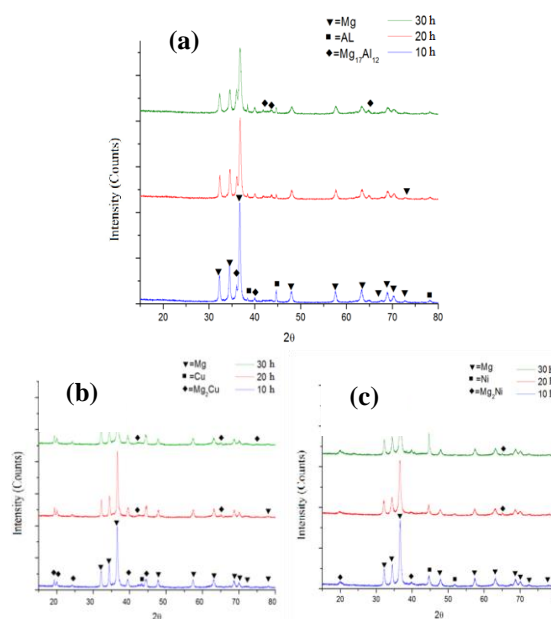



Fig. 2. XRD pattern of (a) Mg10wt%Al (b) Mg10wt%Cu (c) Mg10wt%Ni

3.3 Scanning Electron Microscopy (SEM)

Fig. 3 shows SEM micrograph for Mg10wt%Al, revealing that all powder shape through mechanical alloying are polygonal, it can be assumed that during mechanical alloying process, powders encountering collision and deformation of the initial form.

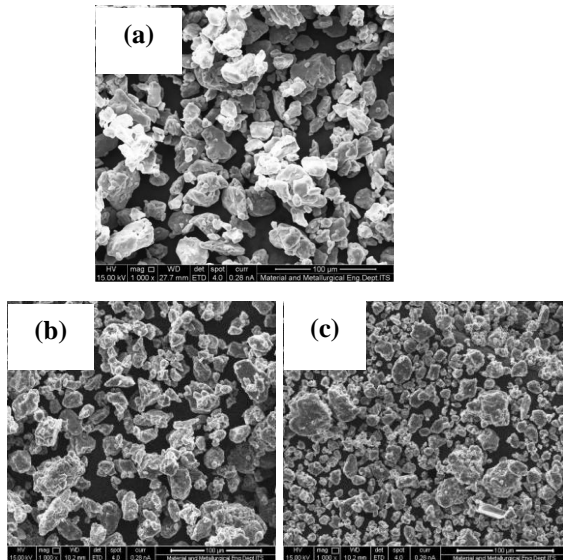



Fig. 3. SEM micrographs of Mg10wt%Al with milling time (a) 10 hours (b) 20 hours (c) 30 hours

Particle size for Mg10wt%Al with 10, 20, and 30 hours milling times are 15-35μm, 10-30μm, and 5-30μm respectively. It can be assumed that improvement in the milling time generally will result in decreasing of particle size. These decreasing are expected to give higher surface contact area between Mg and hydrogen, hence improve absorption rate. Nevertheless, no homogeneous particles size due to agglomeration and cold welding effect.

Fig. 4 reveals agglomeration and coldwelding on Mg10wt%Cu with 30 hours of milling time. They are part of mechanical alloying process. However, if they are exist in exaggerate way can cause decreasing in absorption and desorption due to the decreasing of surface contact area between Mg and hydrogen.

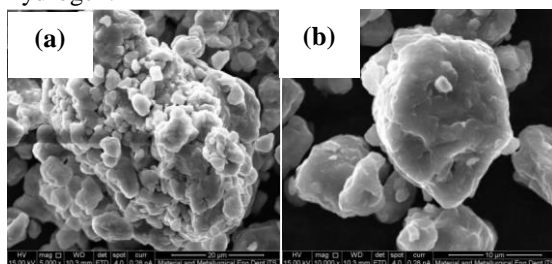
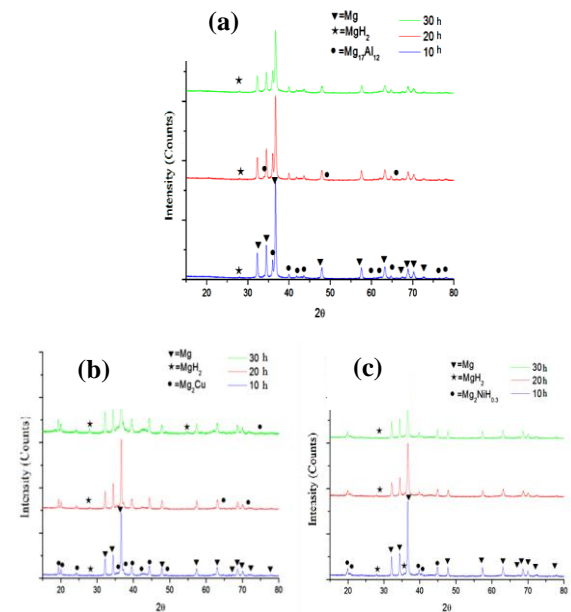



Fig 4. SEM micrograph of Mg10wt%Cu for 30 hours (a) Aglomeration (b) Coldwelding

Fig 5. XRD pattern of (a) Mg10wt%Al (b) Mg10wt%Cu (c) Mg10wt%Ni after hydrogenation

3.4 Hydrogenation Analysis

Hydrogenation test was carried out to evaluate the presence of metal hydride. Fig 5 shows XRD result after hydrogenation. This result reveals the presence of metal hydride, Mg_2H_2, suggesting that addition of Al, Cu, and Ni by mechanical alloying improve absorption properties of Mg, however Mg phase still dominates due to low hydrogen pressure during hydrogenation process. Furthermore, the presence of other phases, $Mg_2NiH_{0.3}$ which is the initial form of Mg_2NiH_4, is identified as well. $Mg_2NiH_{0.3}$ has the same Hexagonal crystal structure with Mg_2Ni also due to low hydrogen pressure, hence hydrogen insert in crystal system of Mg_2Ni.

3.5 Differential Scanning Calorimeter (DSC)

DSC test was performed to observe the quantity, wt%, of absorbed H2 during hydrogenation and desorption onset temperature. By using method analysis in agreement with previous researcher [6], Fig 6 shows wt% of plotting absorbed H_2. Weight percent of absorbed H_2 are in the range 0.1-0.38 wt%, Mg10wt%Al has the maximum value, 0.387 wt%, with the milling time 20 hours (see fig 6). The low values of absorbed H_2 on samples are due to the low hydrogen pressure, 3 atm, during hydrogenation process. In this case, at the initial hydrogen atom absorption by metal required enough high pressure to diffuse hydrogen atom towards sub-surface samples [7].

In addition, increasing in milling time from 10 to 20 hours raise the number of absorbed wt% H_2. This is due to different particle size, in agreement with SEM result which shows 20 hours milling time cause smaller particles as compared to 10 hours. In this way, smaller particle size result in higher contact surface area between sample and hydrogen, therefore, bigger chance of hydrogen to get into sample particles and finally cause increasing in

absorption hydrogen rate [2, 8].

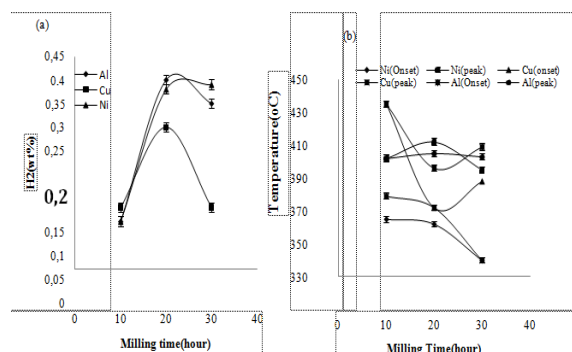



Fig 6. (a)Graphic changes of absorbed wt%H_2 versus variation in milling time (b) Graphic changes milling time versus onset and desorption peak temperature.

However, the decrease of absorbed wt% H_2 is detected due to agglomeration and cold welding process during mechanical alloying; hence particles clump together with each other. Excessive of those processes during this time disserve in absorption process of H_2 because they can decrease the surface contact area of sample.

Fig 6(b) shows onset and desorption peak temperature of H_2. Onset and desorption peak temperature of additional unsure is lower as compared to pure powders MgH_2 in previous result [9], Mg10wt%Al has the lowest onset temperature with 30 hours milling time, *ca.* 341.49^{o}C. Alteration onset and peak temperature on DSC test reveals desorption activation energy. The lower the

Temperature the smaller activation energy, therefore result in lower temperature needed to obtain optimum absorption rate.

IV. SUMMARY

The $Mg_{17}Al_{12}$, Mg_2Cu, and Mg_2Ni alloy have succesfully synthesized by mechanical alloying method. Excessive in aglomeration dan coldwelding process during mechanical alloying cause bigger particle size. The decrease in onset desorption temperature is due to higher weight percent of absorbed H_2 because of smaller particles size. Al and Cu act as catalyst to accelerate adsorption rate and hydrogen desorption. Ni serves as alloying which is reacted with hydrogen and modified sample thermodynamically. Mg10wt%Al with the milling time 20 hours at 200°C and 1 hour holding time has the highest weight percent (0.38wt% H_2), whereas Mg10wt%Al with the milling time 30 hours has the lowest onset desorption temperature (341.49^{o}C).

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26 ARAHAN ADAPTASI KAWASAN RAWAN ABRASI BERDASARKAN KERENTANAN DI PESISIR KABUPATEN TUBAN

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Abstrak – *Pada tahun 1993 hingga 2009, 3,6 juta m2 wilayah pesisir Kabupaten Tuban hilang akibat abrasi. Wilayah pesisir tersebut adalah salah satu pusat pertumbuhan ekonomi di Jawa Timur menurut berbagai rencana tata ruang. Namun, kondisi masyarakat dan kawasan yang cukup rentan terhadap abrasi menjadi faktor yang menghambat pembangunan dan pengembangan ekonomi. Oleh karena itu, penelitian ini merumuskan arahan adaptasi dalam pengurangan kerentanan pesisir . Penelitian ini menggunakan metode AHP untuk menentukan bobot faktor yang berpengaruh terhadap kerentanan masyarakat. Tahap selanjutnya adalah penentuan kerentanan yang menggunakan analisa weighted overlay dan cluster analysis dengan memperhatikan bobot faktor tersebut. Selanjutnya, penelitian ini mentipologikan desa-desa wilayah penelitian berdasarkan klasifikasi kerentanan dengan menggunakan analisa klaster. Terakhir, perumusan arahan adaptasi dilakukan dengan menggunakan analisa triangulasi berdasarkan tipologi tersebut . Dari hasil analisa, didapat hasil bahwa terdapat dua zona kerentanan (rendah dan sedang) dan lima tipologi desa. Zona kerentanan rendah berada pada tipologi 1, 3,dan 4. Sedangkan zona kerentanan sedang berada pada tipologi 2 (Desa Palang) dan 5 (Desa Socorejo, Sugihwaras, dan Tasikharjo). Perumusan arahan adaptasi dilakukan hanya pada zona kerentanan sedang didua tipologi (2 dan 5). Arahan adaptasi untuk tipologi 2 memiliki fokus pada pengurangan laju abrasi dengan perbaikan kualitas dan kuantitas vegetasi penahan laju abrasi serta pembangunan tanggul laut, peningkatan efektivitas penataan ruang, pembangunan infrastruktur tahan bencana, dan peningkatan pengetahuan masyarakat mengenai bencana abrasi. Sedangkan arahan adaptasi untuk tipologi 5 memiliki fokus pada pembangunan breakwater jenis offshore breakwater, peningkatan efektivitas penataan ruang, pembangunan infrastruktur tahan bencana, serta peningkatan pengetahuan masyarakat mengenai bencana abrasi.*

Kata kunci: *abrasi, kerentanan, adaptasi, pesisir kabupaten tuban*

I. PENDAHULUAN

Sebagai kawasan yang berbatasan dengan lautan, pesisir juga merupakan kawasan yang rawan terjadi permasalahan, seperti abrasi, penurunan kualitas lingkungan, pendangkalan pantai, serta kerusakan ekosistem. Fenomena ini terutama berlangsung di kawasan pesisir yang padat penduduknya dan tinggi tingkat pembangunannya, seperti Selat Malaka, Pantai Utara Jawa, Sulawesi Selatan dan Bali. Salah satu fenomena yang patut menjadi perhatian adalah abrasi. Abrasi merupakan proses terjadinya pengikisan daratan oleh gelombang sehingga menyebabkan hanyutnya substrat dan berkurangnya luas daratan (Miyasyiwi dan Prasetya, 2011). Terjadinya perubahan garis pantai sangat dipengaruhi oleh proses-proses yang terjadi pada daerah sekitar pantai, dimana pantai selalu beradaptasi dengan berbagai kondisi yang terjadi (Azhar, dkk. 2012). Salah satu kawasan pesisir yang rentan terhadap kerusakan lingkungan akibat abrasi adalah kawasan pesisir Kabupaten Tuban. Dari hasil hasil overlay selama 1993 hingga 2009, setidaknya 3,6 juta m2 wilayah pesisir Kabupaten Tuban hilang akibat abrasi, dan rata-rata setiap tahun abrasi memakan 5-6 meter wilayah pesisir dan dalam rentang tahun 2002-2012 total panjang pantai yang mengalami abrasi sebesar 7.630 m dengan total lebar abrasi sebesar 272 m (Dinas Perikanan dan Kelautan Kabupaten Tuban, 2012).

Di sepanjang pesisir Kabupaten Tuban terdapat banyak infrastruktur dan pusat-pusat kegiatan, antara lain jalan arteri primer Pantura yang menghubungkan Jawa Timur- Jawa Barat, pelabuhan, pergudangan, industri, permukiman,

dan pariwisata. Kawasan pesisir tersebut direncanakan sebagai kawasan Industri Terpadu Jawa Timur dengan adanya rencana pembangunan pelabuhan, pengembangan kota perikanan dan pelabuhan, serta pengembangan kawasan minapolitan (RTRW Kab. Tuban 2010). Sebagai pusat kegiatan dan ekonomi, kawasan pesisir Kabupaten Tuban tersebut rentan terancam keberlanjutan perkembangannya jika abrasi tidak segera diatasi. Kerentanan (vulnerability) adalah suatu kondisi yang ditentukan oleh faktor- faktor atau proses-proses fisik, sosial, ekonomi, dan lingkungan yang mengakibatkan peningkatan kerawanan masyarakat dalam menghadapi bahaya (hazards) (Disaster Recovery and Mitigation Handbook, 2004). Sehingga tujuan dari penelitian ini adalah melakukan perumusan arahan adaptasi kawasan rawan abrasi berdasarkan kerentanan. Tujuan penelitian dicapai dengan menggunakan tiga sasaran, yaitu menentukan derajat pengaruh faktor-faktor yang mempengaruhi kerentanan terhadap bencana abrasi di pesisir Kabupaten Tuban, menentukan tipologi kawasan berdasarkan karakteristik kerentanan terhadap abrasi dan merumuskan arahan adaptasi kawasan rawan abrasi berdasarkan tingkat kerentanan. Fokus penelitian ini adalah 22 desa yang ada di pesisir Kabupaten Tuban, yaitu Desa Panyuran, Tasikmadu, Kradenan, Gesikharjo, Palang, Glodog, Leran Kulon, Karangagung, Beji, Mentoso, Remen, Kaliuntu, Socorejo, Sugihwaras, Tasikharjo, Jenu, Wadung, Gadon, Tambakboyo, Pabean, Bancar, dan Sukolilo.

Gambar 1. Batas Wilayah Penelitian

METODE

A. Faktor dan Variabel Penelitian

Dalam mengidentifikasi kerentanan kawasan, digunakan 4 faktor, yaitu faktor lingkungan, faktor fisik, faktor sosial, dan faktor ekonomi. Faktor lingkungan terdiri dari variabel luasan kawasan resapan air, luasan hutan mangrove, dan luasan kawasan terumbu karang. Faktor fisik terdiri dari variabel presentase kawasan terbangun, kepadatan bangunan, panjang jalan, jaringan listrik, jaringan telekomunikasi, dan jaringan PDAM. Faktor sosial terdiri dari variabel kepadatan penduduk, laju pertumbuhan penduduk, dan presentase penduduk usia lansia dan balita. Faktor ekonomi terdiri dari variabel presentase penduduk yang bekerja di sektor rentan dan presentase penduduk miskin.

B. Metode dan Teknik Analisa Data

Dalam menentukan derajat pengaruh faktor, teknik analisa yang digunakan adalah *Analytical Hierarchy Process* (AHP) setelah terlebih dahulu menentukan responden melalui analisa stakeholder. Untuk menentukan zonasi kerentanan kawasan menggunakan teknik analisa *Weighted Overlay* dan untuk menentukan kelompok kawasan digunakan analisa kluster dengan metode *Hierarchical Cluster*. Untuk menentukan arahan adaptasi, digunakan analisa triangulasi.

AHP adalah teknik analisa yang mengorganisasikan suatu informasi untuk menentukan alternatif pilihan yang paling disukai (prioritas) berdasarkan persepsi rasional seseorang (*expert*/tenaga ahli). Persepsi tenaga ahli ini dihasilkan dari kuisioner AHP yang telah disebar sebelumnya (Saaty, 1980).

Weighted Overlay merupakan salah satu fasilitas yang ada dalam ArcGis 9.3 yang mengkombinasikan berbagai macam input dalam bentuk peta grid dengan pembobotan (weighted faktor) dari AHP sehingga menghasilkan analisis yang terintegrasi. Hasil peta keluaran menunjukkan pengaruh tiap input tersebut pada suatu wilayah geografis.

Setelah diketahui zonasi kerentanan pada kawasan penelitian, selanjutnya dilakukan pengelompokkan kawasan berdasarkan karakteristik kerentanan. Pengelompokkan ini bertujuan untuk memudahkan perumusan pola adaptasi yang nantinya akan dilakukan. Pengelompokkan dilakukan dengan menggunakan analisa klaster. Analisis klaster adalah teknik statistik multivariat untuk mengidentifikasi sekelompok objek yang memiliki kemiripan karakteristik tertentu sehingga dapat dipisahkan dari kelompok objek lainnya Analisis

klaster pada prinsipnya digunakan untuk mereduksi data, yaitu proses untuk meringkas sejumlah variabel menjadi lebih sedikit dan menamakannya sebagai klaster.

Setelah dilakukan pengelompokan berdasarkan karakteristik kerentanan, selanjutnya dirumuskan arahan adaptasi. Arahan adaptasi dilakukan dengan menggunakan analisa triangulasi. Analisa triangulasi merupakan gabungan atau kombinasi berbagai metode yang dipakai untuk mengkaji fenomena yang saling terkait dari sudut pandang dan perspektif yang berbeda.

HASIL

A. Derajat Pengaruh Faktor dan Variabel

Dalam menentukan derajat pengaruh faktor-faktor yang mempengaruhi kerentanan masyarakat terhadap bencana abrasi, metode yang digunakan adalah *Analytical Hierarchy Process* (AHP). Langkah pertama dalam analisa ini adalah melakukan penyebaran kuesioner kepada responden terkait bobot kepentingan faktor yang telah ditentukan. Responden yang dilibatkan dalam perumusan bobot faktor ada 8 orang yang telah ditentukan sebelumnya melalui analisa stakeholder.

Kriteria dan alternatif hasil penyebaran kuesioner dinilai melalui perbandingan berpasangan (*pairwise comparation*) dari pendapat masing-masing stakeholder yang kemudian dilakukan proses *combine* untuk mendapatkan derajat kepentingan dari masing-masing faktor yang berpengaruh. Dalam proses analisa, kriteria yang pertama kali dibandingkan adalah kriteria utama, yaitu faktor kerentanan lingkungan, kerentanan fisik, kerentanan sosial, dan kerentanan ekonomi.

Dari analisa, didapat hasil bahwa faktor kerentanan yang paling mempengaruhi kerentanan terhadap bencana abrasi adalah faktor kerentanan fisik dengan nilai *Eigen Value* 0,358, kemudian kerentanan lingkungan dengan *Eigen Value* 0,295, kerentanan ekonomi dengan *Eigen Value* 0,203, dan kerentanan sosial dengan *Eigen Value* 0,144. Sedangkan rasio konsistensi (CR) dalam pembobotan faktor kerentanan sebesar 0,00093.

Dalam faktor kerentanan lingkungan, variabel yang paling mempengaruhi kerentanan terhadap bencana abrasi adalah variabel kawasan hutan mangrove dengan nilai *Eigen Value* 0,637 kemudian kawasan terumbu karang dengan *Eigen Value* 0,201, dan kawasan resapan air dengan *Eigen Value* 0,162. Sedangkan rasio konsistensi dalam pembobotan variabel pada faktor kerentanan lingkungan sebesar 0,00078.

Dalam faktor kerentanan fisik, variabel yang paling mempengaruhi kerentanan terhadap bencana abrasi adalah variabel rasio panjang jalan dengan nilai *Eigen Value* 0,282, kemudian presentase kawasan terbangun dengan *Eigen Value* 0,264, kepadatan bangunan dengan *Eigen Value* 0,176, jaringan listrik dengan *Eigen Value* 0,152, jaringan PDAM dengan *Eigen Value* 0,077, dan jaringan telepon dengan *Eigen Value* 0,049. Sedangkan rasio konsistensi dalam pembobotan faktor kerentanan fisik sebesar 0,01.

Dalam faktor kerentanan sosial, variabel yang paling mempengaruhi kerentanan terhadap bencana abrasi adalah variabel laju pertumbuhan penduduk dengan *Eigen Value* 0,357, kemudian presentase penduduk usia lansia- balita dengan nilai *Eigen Value* 0,348, dan kepadatan penduduk dengan *Eigen Value* 0,295. Sedangkan rasio konsistensi dalam pembobotan faktor kerentanan sosial sebesar 0,0001.

Dalam faktor kerentanan ekonomi, variabel yang paling mempengaruhi kerentanan terhadap bencana abrasi adalah variabel presentase penduduk yang bekerja di sektor rentan dengan *Eigen Value* 0,641, kemudian presentase penduduk miskin dengan nilai *Eigen Value* 0,359. Sedangkan rasio konsistensi dalam pembobotan faktor kerentanan ekonomi sebesar 0,00.

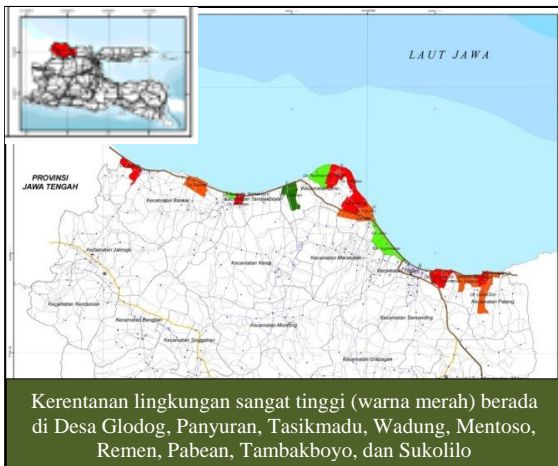
Bobot hasil analisa di atas nantinya akan dijadikan masukan dalam proses analisa selanjutnya, yaitu penentuan zona kerentanan kawasan.

B. Zonasi Kerentanan

Zonasi kerentanan dilakukan dengan analisa *Weighted Overlay* GIS. Langkah pertama tahapan analisa *Weighted Overlay* adalah menentukan klasifikasi tingkat faktor. Dalam penelitian ini, klasifikasi dilakukan dengan 5 kelas faktor, yaitu sangat rendah dengan nilai 1, rendah (2), sedang (3), tinggi (4), dan sangat tinggi (5).

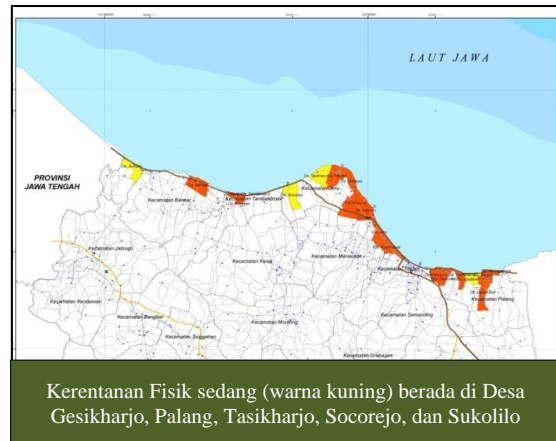
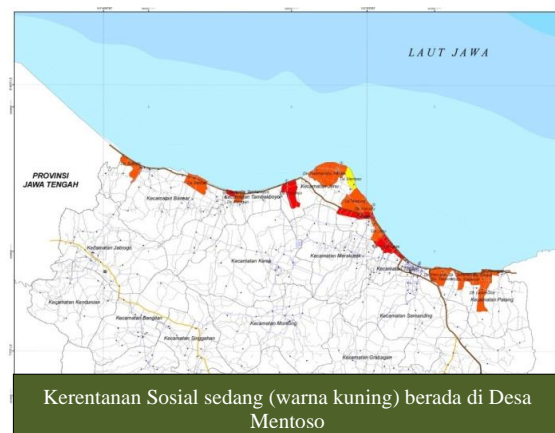
Setelah ditentukan klasifikasi faktor, selanjutnya adalah menentukan bobot pengaruh faktor dan variabel. Bobot pengaruh faktor dan variabel yang digunakan adalah bobot hasil perhitungan AHP pada sasaran sebelumnya. Dikarenakan dalam analisa *Weighted Overlay* bobot pengaruh harus dalam bentuk persen, maka bobot pengaruh ini juga akan dikonversi ke dalam persen.

Perhitungan analisa *Weighted Overlay* dilakukan

untuk semua faktor kerentanan, yaitu kerentanan lingkungan, kerentanan fisik, kerentanan sosial, dan kerentanan ekonomi.

Gambar 2. Zonasi Kerentanan Lingkungan

Untuk faktor kerentanan lingkungan, klasifikasi juga dilakukan melalui 5 kelas kerentanan dengan bobot variabel kawasan resapan air sebesar 16,2%, variabel kawasan hutan mangrove dengan bobot 63,7%, dan kawasan terumbu karang dengan bobot 20,1%.

Dari hasil analisa, didapat hasil bahwa terdapat 4 zona kerentanan lingkungan, yaitu zona kerentanan lingkungan sangat tinggi, tinggi, rendah, dan sangat rendah.

Untuk faktor kerentanan fisik, klasifikasi juga dilakukan melalui 5 kelas kerentanan dengan bobot variabel presentase kawasan terbangun sebesar 26,4%, kepadatan bangunan sebesar17,6%, panjang jalan sebesar 28,2%, jaringan listrik sebesar 15,2%, jaringan telekomunikasi sebesar 4,9%, dan jaringan PDAM sebesar 7,7%. Dari hasil analisa, didapat hasil bahwa terdapat 2 zona kerentanan fisik, yaitu zona kerentanan fisik sedang dan zona kerentanan fisik rendah (*Gambar 3*).

Gambar 3. Zonasi Kerentanan Fisik

Gambar 4. Zonasi Kerentanan Sosial

Untuk faktor kerentanan sosial, klasifikasi juga dilakukan melalui 5 kelas kerentanan dengan bobot variabel kepadatan penduduk sebesar 29,5%, laju pertumbuhan penduduk sebesar 35,7%, dan presentase penduduk usia lansia- balita sebesar 34,8%. Dari hasil analisa, didapat hasil bahwa terdapat 3 zona kerentanan sosial, yaitu zona kerentanan sosial sedang, zona kerentanan sosial rendah, dan zona kerentanan sosial sangat rendah (*Gambar 4*).

Untuk faktor kerentanan ekonomi, klasifikasi juga dilakukan melalui 5 kelas kerentanan dengan bobot variabel presentase penduduk yang bekerja di sektor rentan sebesar 64,1% dan presentase penduduk miskin sebesar 35,9%. Dari hasil analisa, didapat hasil bahwa terdapat 2 zona kerentanan ekonomi, yaitu zona kerentanan ekonomi tinggi dan zona kerentanan ekonomi sedang.

Gambar 5. Zonasi Kerentanan Ekonomi

Setelah ditemukan peta per faktor kerentanan, selanjutnya dilakukan analisa kerentanan kawasan secara keseluruhan dari semua faktor. Bobot pengaruh yang digunakan berdasarkan hasil analisa AHP untuk kelompok faktor kerentanan, yaitu kerentanan lingkungan, kerentanan fisik, kerentanan sosial, dan kerentanan ekonomi, yaitu:

- Kerentanan lingkungan: 0,295 → 29,5%

- Kerentanan fisik : 0,358 → 35,8%

- Kerentanan sosial : 0,144 → 14,4%

- Kerentanan ekonomi : 0,203 → 20,3%

Formula yang digunakan untuk menentukan zona kerentanan keseluruhan dalam analisa Weight Overlay yaitu:

{29,5 * (Lingkungan_raster) + 35,8 * (Fisik_raster) + 14,4 * (Sosial_raster) + 20,3 * (Ekonomi_raster) }

Dalam penentuan zona kerentanan, digunakan lima kelas kerentanan dengan nilai sebagai berikut:

- Zona kerentanan sangat rendah → 1
- Zona kerentanan rendah → 2
- Zona kerentanan sedang → 3
- Zona kerentanan tinggi → 4
- Zona kerentanan sangat tinggi → 5

Dari hasil analisa, didapat hasil bahwa di kawasan penelitian terdapat dua zona kerentanan terhadap bencana abrasi, yaitu kerentanan rendah dan kerentanan sedang. Zona kerentanan rendah terdapat di Desa Karangagung, Glodok, Leren Kulon, Gesikharjo, Kradenan, Tasikmadu, Panyuran, Beji, Kaliuntu, Wadung, Mentoso, Remen, Tambakboyo, Pabean, Gadon, Bancar, Sukolilo. Sementara zona kerentanan sedang berada di Desa Palang, Desa Sugihwaras, Desa Jenu, Desa Tasikharjo, dan Desa Socorejo.

Walaupun tingkat kerentanan menunjukkan kerentanan rendah dan sedang, namun ada kemungkinan terjadi peningkatan kerentanan akibat fenomena *climate change* sehingga harus segera diatasi. Untuk lebih jelasnya, zona tingkat kerentanan terhadap bencana abrasi dapat dilihat pada Gambar 6

Gambar 6. Peta Zonasi Kerentanan

Pentipologian desa Berdasarkan Karakteristik Kerentanan

Setelah diketahui zonasi kerentanan pada kawasan penelitian, selanjutnya dilakukan penentuan tipologi desa berdasarkan karakteristik kerentanan. Tipologi ini bertujuan untuk memudahkan perumusan pola adaptasi dan menjadikan adaptasi lebih efektif karena dilakukan berdasarkan karakteristik kerentanan. Analisa dilakukan dengan Analisa Kluster dengan metode *Hierarchical Cluster*. Dalam proses penentuan tipologi ini dapat dibagi menjadi tiga tahap yaitu input, proses analisis dan output analisis.

Input dari analisa ini adalah data pada variabel-variabel kerentanan yang kemudian akan diklasifikasi berdasarkan kelas-kelas kerentanan (kerentanan sangat rendah, rendah, sedang, tinggi, dan sangat tinggi) untuk memudahkan dalam memperoleh gambaran karakteristik kawasan. Input tersebut dianalisa sehingga diketahui kelompok kawasan yang memiliki kesamaan karakteristik. Dari hasil analisa, terdapat lima tipologi kawasan, yaitu:

- Tipologi 1 (Kawasan Yang Memiliki Tingkat Kerentanan Lingkungan Dan Ekonomi Tinggi, Namun Kerentanan Fisik Sedang Dan Kerentanan Sosial Rendah). Terdiri dari Desa Panyuran, Tasikmadu, Kradenan, Gesikharjo, Glodog, Leren Kulon, Mentoso.

- Tipologi 2 (Kawasan Yang Memiliki

Tingkat Kerentanan Lingkungan Dan Ekonomi Sangat Tinggi, Sementara Kerentanan Fisik Dan Kerentanan Sosial Sedang). Terdiri dari Desa Palang.

- Tipologi 3 (Kawasan Yang Memiliki Tingkat Kerentanan Lingkungan Dan Ekonomi Tinggi, Sedangkan Kerentanan Fisik Dan Kerentanan Sosial Rendah). Terdiri dari Desa Karangagung, Beji, Kaliuntu, Gadon, Tambakboyo, Pabean.
- Tipologi 4 (Kawasan Yang Memiliki Kerentanan Lingkungan, Kerentanan Ekonomi, Dan Kerentanan Fisik Tinggi, Namun Kerentanan Sosial Rendah). Terdiri dari Desa Remen, Jenu, Wadung, Bancar, Sukolilo.
- Tipologi 5 (Kawasan Yang Memiliki Kerentanan Lingkungan Rendah, Kerentanan Ekonomi Tinggi, Kerentanan Fisik Sedang, Dan Kerentanan Sosial Rendah). Terdiri dari Desa Socorejo, Sugihwaras, Tasikharjo.

Dari kelima tipologi di atas, dapat dilihat bahwa zona kerentanan rendah berada pada kawasan dengan tipologi 1, 3, dan 4. Sementara zona kerentanan sedang berada pada kawasan dengan tipologi 2 dan tipologi 5. Hasil kompilasi ini akan menjadi input dalam penentuan arahan adaptasi di kawasan penelitian.

D. Perumusan Arahan Adaptasi Kawasan Rawan Abrasi Berdasarkan Tingkat Kerentanan

Triangulasi dilakukan berdasarkan zonasi kerentanan dan tipologi kawasan. Arahan dirumuskan pada kawasan yang memiliki variabel dengan karakteristik kerentanan sedang hingga sangat tinggi. Untuk kawasan dengan karakteristik variabel kerentanan rendah, tidak dirumuskan arahannya dikarenakan belum terlalu diperlukan. Oleh karena itu, dalam penelitian ini, arahan adaptasi hanya dirumuskan untuk zona kerentanan sedang, yaitu tipologi kawasan 2 dan tipologi 5.

Tabel 1. Arahan Adaptasi Kawasan Rawan Abrasi

Tipologi 2	
Faktor Lingkungan	- Pemeliharaan kelangsungan fungsi resapan air dan daerah tangkapan air; - Penanaman vegetasi yang memiliki sistem perakaran kuat dan mampu mempercepat penyerapan air - Pengaturan kepadatan bangunan pada kawasan resapan air - Pembuatan *breakwater* jenis *offshore breakwater* di depan hutan *Mangrove* - Perbaikan pola penanaman mangrove sesuai ketahanan jenis dalam adaptasinya dengan kondisi lingkungan habitat pesisir. Pada bagian yang berbatasan langsung dengan laut sebaiknya ditanam dengan jenis-jenis *Avicennia sp* dan *Sonneratia sp*, kemudian di bagian belakangnya dengan *Rhizophora sp* dan *Bruguiera sp*. - Menguatkan penetapan dan pelaksanaan kebijakan mengenai perlindungan lingkungan laut; - Konservasi terumbu karang, baik berupa terumbu karang alami atau buatan - Pembuatan rumpon sebagai habitat terumbu karang buatan
Faktor Fisik	- peningkatan efektivitas penataan ruang dan kelembagaan - Mengurangi pertumbuhan kawasan terbangun dengan memperketat proses ijin mendirikan bangunan (IMB) - Pengendalian pembangunan bangunan dengan ketat melalui peraturan zonasi - Pengarahan distribusi kepadatan lahan sesuai daya dukung dan karakter kawasan - Pengarahan penataan kawasan padat sebagai kawasan pembangunan kompak dan terpadu melalui pengaturan peruntukan campuran serta jenis kepadatan yang beragam - Pemberian insentif berupa penyediaan fasilitas bagi kepentingan publik - Penguatan struktur dan material jalan yang tahan terhadap bencana. - Perlindungan infrastruktur jalan berupa tanggul laut

	- Pembangunan infrastruktur dan utilitas tahan bencana
Faktor Sosial	- Melakukan program pendidikan bencana di sekolah- sekolah, baik pendidikan formal maupun informal - Sosialisasi bencana kepada masyarakat melalui musrenbang dan forum warga - Perbaikan kualitas SDM melalui perbaikan sistem pendidikan - Peningkatan ketangguhan masyarakat rentan melalui mekanisme dukungan ekonomi (kredit skala kecil, pinjaman tunai untuk memulai usaha) dan sistem dukungan sosial.
Faktor Ekonomi	- Merumuskan mata pencaharian alternatif yang tidak rentan - Pengadaan kemitraan antara masyarakat, dunia usaha, dan pemerintah dalam perbaikan ekonomi masyarakat - Mengurangi beban pengeluaran masyarakat miskin; - Meningkatkan kemampuan dan pendapatan masyarakat miskin melalui bantuan dana; - Mengembangkan dan menjamin keberlanjutan usaha ekonomi mikro dan kecil; dan - Mensinergikan kebijakan dan program penanggulangan kemiskinan.
Tipologi 5	
Faktor Fisik	- Penguatan struktur dan material jalan yang tahan terhadap bencana. - Perlindungan infrastruktur jalan berupa tanggul laut - Pembangunan infrastruktur dan utilitas tahan bencana - Melakukan penyimpanan air melalui pembuatan tampungan air hujan, kolam, embung, atau waduk.
Faktor Sosial	- Perbaikan kualitas SDM melalui perbaikan sistem pendidikan - Peningkatan ketangguhan masyarakat rentan melalui mekanisme dukungan ekonomi (kredit skala kecil, pinjaman tunai untuk memulai usaha) dan sistem dukungan sosial.
Faktor Ekonomi	- Merumuskan mata pencaharian alternatif yang tidak rentan - Pengadaan kemitraan antara masyarakat, dunia usaha, dan pemerintah dalam perbaikan ekonomi masyarakat - Mengurangi beban pengeluaran masyarakat miskin - Pemberian bantuan dana kepada masyarakat miskin - Mengembangkan dan menjamin keberlanjutan usaha ekonomi mikro dan kecil - Mensinergikan kebijakan dan program penanggulangan kemiskinan

Sumber : Hasil Analisa 2013

PEMBAHASAN

Dari hasil penelitian, terlihat bahwa kawasan pesisir Kabupaten Tuban termasuk zona kerentanan rendah dan sedang terhadap bencana abrasi. Walau demikian, tingkat kerentanan dapat bertambah di masa yang akan datang dengan adanya permasalahan *global warming* dan *climate change*. Sehingga perlu diantisipasi sejak awal, yaitu melalui adaptasi kawasan tersebut agar dapat bertahan dari bencana.

Adaptasi merupakan salah satu bagian dari konsep manajemen resiko bencana yang termasuk dalam pengurangan resiko bencana. Pengelolaan resiko bencana bertujuan untuk mengurangi, atau menghindari, potensi kerugian dari bahaya, menjamin bantuan cepat dan tepat untuk korban bencana, dan mencapai pemulihan yang cepat dan efektif (Warfield, 2008).

Arahan adaptasi yang telah dirumuskan terdiri dari beberapa arahan berdasarkan masing-masing faktor kerentanan, yaitu faktor lingkungan, fisik, sosial, dan ekonomi. Pembagian tersebut bertujuan untuk memudahkan dilakukannya adaptasi. Hal ini dengan mengambil asumsi bahwa kerentanan di masa depan akan dihasilkan dari interaksi adaptasi dengan kerentanan di masa kini (Pamungkas *et al.*, 2011)

Arahan adaptasi yang telah dirumuskan juga menyesuaikan dengan tipologi adaptasi dalam siklus Disaster Risk Management (DRM). Disaster Risk Management Cycle atau siklus pengelolaan resiko bencana merupakan strategi atau pendekatan

dalam adaptasi yang berupa tahapan-tahapan yang saling berkesinambungan pola adaptasi terhadap pengelolaan resiko bencana (ADPC, 2005). Tahapan tersebut adalah mitigasi, kesiapsiagaan, respon dan rehabilitasi (recovery) Shah Alam Khan (2008); Moe et al. (2007); FEMA (2006); Atmanand (2003).

a. *Mitigation* (Mitigasi)

Mitigasi merupakan upaya adaptasi yang dilakukan sebelum terjadinya bencana (pre-disaster) untuk meminimalisir efek dari bencana.

Pada tahap mitigasi, adaptasi untuk desa dengan tipologi 2 adalah pelestarian dan revitalisasi ekosistem mangrove dan terumbu karang, peningkatan efektivitas penataan ruang di kawasan rentan, perbaikan kualitas SDM, merumuskan rencana ruang terbuka hijau (RTH) di sempadan pantai yang berupa hutan mangrove dan vegetasi lainnya, pengetatan kebijakan terkait perlindungan lingkungan pesisir, pembangunan struktur pemecah gelombang atau *sea wall*, pembangunan infrastruktur dan utilitas tahan bencana serta peningkatan kemampuan ekonomi masyarakat kelompok ekonomi lemah.

Adaptasi untuk desa dengan tipologi 5 untuk tahap ini adalah peningkatan efektivitas penataan ruang, peningkatan ketangguhan masyarakat rentan baik dalam bidang sosial ataupun ekonomi, pembangunan *breakwater* jenis *offshore breakwater*, pembuatan penampungan air hujan (waduk, ponds, embung, dsb.) dan membuka/menciptakan peluang kerja alternatif untuk menggantikan mata pencaharian yang tergolong rentan.

b. *Preparedness* (Kesiapsiagaan)

Menurut Khan (2010), kesiapsiagaan adalah perencanaan dalam merespon terjadinya bencana, misalnya dengan menyiapkan rencana kontigensi, pelatihan evakuasi bencana dan *Early Warning System*.

Pada tahap kesiapsiagaan, adaptasi untuk desa dengan tipologi 2 adalah dengan sosialisasi dan edukasi mengenani bencana abrasi terhadap masyarakat.

Adaptasi untuk desa dengan tipologi 5 untuk tahap ini adalah berupa sosialisasi dan edukasi mengenai bencana abrasi terhadap masyarakat.

c. Response

Khan (2010) berpendapat bahwa respons adalah usaha untuk meminimalisir bahaya yang ditimbulkan saat terjadinya bencana. Misalnya melalui kegiatan *search and resque*, pertolongan terhadap korban bencana, dan sebagainya.

Pada tahap respon, adaptasi untuk desa dengan tipologi 2 adalah pertolongan terhadap korban bencana dan bangunannya.

Adaptasi untuk desa dengan tipologi 5 untuk tahap ini adalah pertolongan terhadap korban bencana dan bangunannya.

Dalam konteks bencana abrasi, pada tahap respon hanya dapat dilakukan pertolongan kepada korban dan bangunan di sekitarnya. Hal itu dikarenakan bencana abrasi cenderung tidak menimbulkan korban jiwa yang banyak. Sebagian besar kasus abrasi hanya menimbulkan kerusakan terhadap bangunan dan lingkungan.

d. *Rehabilitation* (Rehabilitasi)

Menurut UNDP (2004) rehabilitasi adalah tindakan yang diambil setelah bencana dengan maksud untuk memulihkan atau meningkatkan kondisi kehidupan pra-bencana pada masyarakat yang terkena dampak. Rusty (2011) menyatakan rehabilitasi merupakan pemulihan dari kejadian bencana yang berdampak kepada masyarakat untuk bantuan dana, penyedia kesehatan dan tempat pengungsian, sehingga dapat dilakukan rekonstruksi dalam jangka panjang. Menurut Khan (2010), rehabilitasi adalah pengembalian kondisi lingkungan masyarakat seperti sebelum terjadinya bencana.

Pada tahap rehabilitasi, adaptasi untuk desa dengan tipologi 2 adalah perbaikan kawasan lindung sempadan pantai dan pembangunan atau perbaikan kembali infrastruktur dan bangunan yang rusak akibat abrasi.

Adaptasi untuk desa dengan tipologi 5 untuk tahap ini sama dengan tipologi 2, yaitu perbaikan kawasan lindung sempadan pantai dan pembangunan atau perbaikan kembali infrastruktur dan bangunan yang rusak akibat abrasi.

Jika melihat beragam adaptasi diatas, arahan adaptasi untuk abrasi lebih fokus pada tahap mitigasi. Hal itu dikarenakan bencana abrasi merupakan bencana yang terjadi dalam jangka waktu yang cukup lama dan dampaknya tidak bisa langsung dirasakan, namun dalam jangka waktu tertentu dapat menimbulkan kerugian bagi masyarakat pesisir, seperti kerusakan infrastruktur/ properti, bahkan mengancam keselamatan jiwa (Carter, 1993).

KESIMPULAN

Adapun kesimpulan dari penelitian ini adalah sebagai berikut:

1. Terdapat dua zona kerentanan di kawasan penelitian, yaitu zona kerentanan rendah dan zona kerentanan sedang.
2. Tipologi kerentanan di kawasan penelitian digolongkan menjadi lima tipologi, dengan 2 tipologi berkerentanan sedang yaitu;
   a. Tipologi 2 (Kawasan yang Memiliki Tingkat Kerentanan Lingkungan dan Ekonomi Sangat Tinggi, sementara Kerentanan Fisik dan Kerentanan Sosial Sedang)
   b. Tipologi 5 (Kawasan yang Memiliki Kerentanan Lingkungan Rendah, Kerentanan Ekonomi Tinggi, Kerentanan Fisik Sedang, dan Kerentanan Sosial Rendah)
3. Prioritasi arahan adaptasi diprioritaskan pada dua tipologi berkerentanan sedang. Arahan adaptasi untuk masing-masing kawasan dapat dilakukan berdasarkan faktor-faktor yang memiliki kerentanan tinggi dan sedang, sedangkan arahan untuk faktor yang memiliki kerentanan rendah belum perlu untuk dilakukan.
4. Arahan adaptasi pada desa dengan tipologi 2 difokuskan dalam hal pengurangan laju abrasi dengan perbaikan kualitas dan kuantitas vegetasi penahan laju abrasi serta pembangunan tanggul laut, peningkatan efektivitas penataan ruang, pembangunan infrastruktur tahan bencana, dan peningkatan pengetahuan masyarakat mengenai bencana abrasi.
5. Arahan adaptasi pada desa dengan tipologi 5 difokuskan pada pembangunan breakwater jenis offshore breakwater, peningkatan efektivitas penataan ruang, pembangunan infrastruktur tahan bencana, serta peningkatan pengetahuan masyarakat mengenai bencana abrasi.

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Sistem Monitoring Kadar Air Tanah Pada Tanggul Berbasis Web (Implementasi Kasus Tanggul Jebol)

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Abstrak – *Terwujudnya penanggulangan bencana secara cepat, tepat, efektif dan efisien merupakan visi Badan Penanggulangan Bencana Daerah. Banyaknya kerugian yang timbul akibat adanya tanggul jebol di Indonesia merupakan indikasi masih belum tersentuhnya sistem penanggulangan bencana pada area ini. Sebuah tanggul dengan tanah sebagai penyusunnya merupakan fenomena yang dapat diamati perubahan kekuatannya. Kadar air dalam tanah merupakan parameter yang dapat diamati perubahannya berkaitan dengan kekuatan tanggul akibat adanya interaksi tanah dengan air. Dengan adanya sistem monitoring kadar air dalam tanah, perubahan parameter kekuatan tanggul dapat menjadi suatu data yang penting apabila terjadi tanggul jebol. Akuisi data sensor kadar air menggunakan mikroprosessor atmega 16 Sistem monitoring yang dikembangkan adalah berbasis web dengan database MySql.*

Kata kunci: *Tanggul jebol, sensor kadar air,ultrasonik sensor, sistem monitoring*

II. PENDAHULUAN

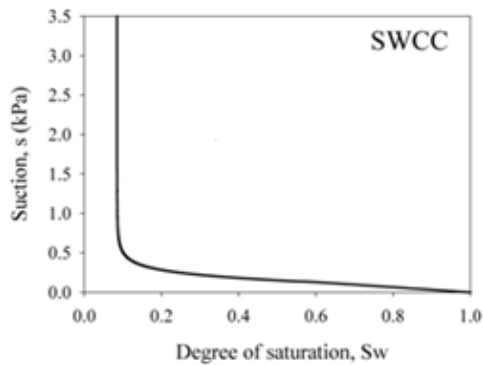
Masih banyaknya kejadian tanggul jebol di Indonesia perlu perhatian khusus, karena dampak yang ditimbulkan merupakan sebuah ancaman dan kerugian. Negara-negara berkembang dalam menghadapi bencana alam seperti banjir, badai dan gempa bumi seringkali mengakibatkan hilangnya nyawa dan harta benda [1]. Disisi yang lain perkembangan teknologi untuk pencegahan dan mitigasi bencana alam cukup rendah [2]. Peringatan dini kepada masyarakat ketika banjir akan terjadi merupakan solusi efektif karena memberikan warga cukup waktu untuk mengevakuasi dan melindungi aset yang dimiliki.

Kejadian tanggul jebol merupakan fenomena yang identik dengan proses tanah longsor, perubahan kekuatan penyusun tanah dapat diteksi dengan adanya pergerakan pada tanah. Pergerakan atau pergeseran pada badan tanah dapat dideteksi menggunakan fiber optik dengan metode OTDR(*Optical Time Domain Reflectory*) [3], dimana pergerakan badan tanah akan mengakibatkan bengkoknya pipa yang terdapat serat fiber sehingga terjadi keterlambatan dalam pembacaan berkas optik. Penggunaan sensor level air yang dipadukan dengan sensor sudut juga digunakan untuk mengetahui kemungkinan tanah longsor[4].

Sistem monitoring kadar air tanah didesain berbasiskan web, hal ini bertujuan untuk memudahkan pengaksesan data berkaitan dengan kemungkinan bencana tanggul jebol. Metode yang diusulkan adalah mengolah data sensor kadar air menggunakan mikroprosessor atmega 16 yang ditransmisikan menggunakan *wireless communication (xbee)* untuk diolah oleh *web server*..

III. LANDASAN TEORI

Kandungan air dalam tanah merupakan rangkaian proses alami yang menunjukkan adanya pengaruh zat cair terhadap bahan penyusun tanah. Karena tanah bersifat permeabel, sehingga memungkinkan zat cair untuk naik melalui pori-pori tanah. Kekuatan sebuah tanggul dapat didekati menggunakan grafik Soil Water Characteristic Curve

Hal ini dapat ditunjukkan melalui kurva hubungan kebasahan tanah (SWCC), dimana kandungan air tanah (%) dapat dihubungkan dengan suction tanah sebagai penyusunnya. Sebuah keruntuhan tanggul dapat terjadi karena tensor tegangan tanah pada badan tanggul bernilai negative suction (u). Sebuah penelitian menunjukkan kurva hubungan kebasahan tanah dengan nilai suction [5].

Gambar 1. Kurva SWCC yang menunjukkan hubungan kadar air dengan suction tanah.

Dalam pengujian kandungan air dalam tanah pada laboratorium, besaran kandungan air dapat dirumuskan sebagai berikut :

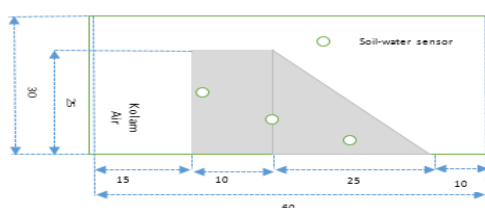
$$\text{Kandungan Air} = \frac{\text{Berat Tanah Basah} - \text{Berat Tanah Kering}}{\text{Berat Tanah Basah}} \times 100\,\% \quad \ldots.\ (1)$$

Pada penggunaan aplikasi berbasis web bertujuan untuk kemudahan dalam mengakses sebuah data secara online berkaitan dengan kondisi parameter tanggul. PHP merupakan bahasa pemrograman yang dinamis untuk mendesain sebuah aplikasi databese berbasis web. Sistem database pada monitoring merupakan suatu kesatuan data yang sangat penting, database yang digunakan adalah MySQL. Integrasi antara web dan system embedded yang diimplementasikan pada sistem monitoring suhu pada ruangan menunjukkan performa yang stabil dengan keuntungan sistem kerja yang tahan lama[6]. Integrasi sistem protokol yang berbeda pada sistem monitoring antara akuisisi data yang berbasis mikrokontroller dan penyajian data yang berbasis web merupakan tantangan pada sistem otomasi kontrol pada industri [7].

IV. IMPLEMENTASI DAN PEMBAHASAN

4.1 Desain Model dan Sensor

4.1.1 Model Fisik Kolam

Model kolam uji yang didesain menggunakan skala 1:200 yang terdiri dari kolam air dan model tanggul. Dengan memperhatikan skala dan daya tampung material pengujian meliputi air dan tanah, kolam uji terbuat dari bahan Akrilik. Panjang kolam uji 60 cm, lebar 30 cm dan tinggi 40 cm. Dalam gambar 1 berikut adalah desain kolam uji yang akan dimodelkan, Pada badan tanggul tertanam sensor kandungan air dalam tanah, yang terletak dengan konfigurasi yang mengacu pada hasil percobaan [5,8].

Gambar 2. Desain kolam uji dengan skala 1: 200

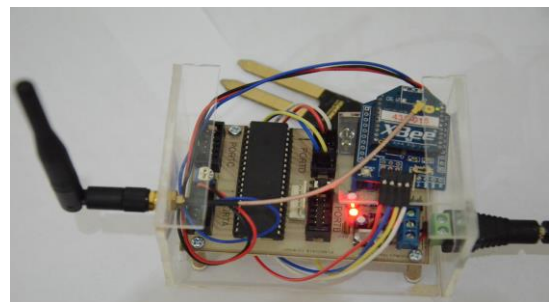
Gambar 3 Model fisik tanggul pada kolam uji

4.1.2 Desain Sensor

Pada badan tanah, perubahan parameter tanah direkam menggunakan sensor kandungan air tanah menggunakan jenis SKU:SEN0114 produk dari dfrobot, dimana sensor ini memiliki sensitivitas pembacaan dalam ADC mikrokontroller 0-900, 0 merupakan hasil pengukuran media pasir kering dan 900 dalam media air. Dengan menggunakan sensor kandungan air tanah berbasis resistansi maka perubahan jumlah air dalam tanah akan mewakili fungsi resistansi. Semakin kecil kandungan air maka resistansi akan semakin besar, sebaliknya semakin kecil resistansi maka indikasi kandungan air semakin besar.

Gambar 5. Sensor kadar air dalam tanah

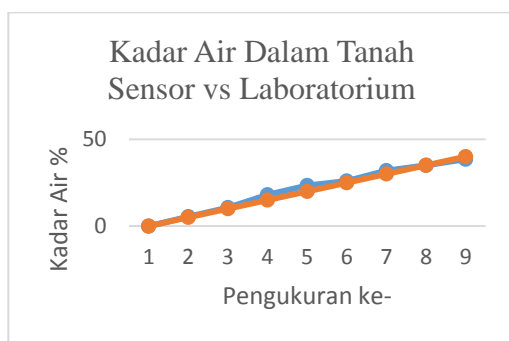
Jenis mikrokontroller yang digunakan adalah Atmega 16, mikrokontroller mengirim data pada komputer server menggunakan komunikasi serial tanpa kabel *(wireless communication*) . berikut adalah tampilan rangkaian yang digunakan dalam pengujian:

Gambar 5. Rangkaian akuisisi data

4.2 Prosedur Pengujian

Studi eksperimen yang dilakukan untuk mendapatkan kandungan air dalam tanah pada badan tanggul telah dikalibrasi dengan hasil pengukuran

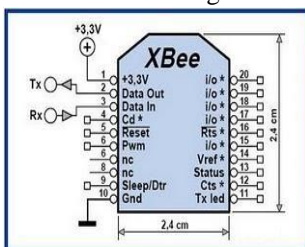
laboratorium. Pada tabel 1 akan ditunjukkan hasil pengukuran dengan sensor dan pengujian di laboratorium mekanika tanah.

Tabel 1. Perbandingan hasil kadar air

Nomor	Pengukuran Sensor	Pengukuran Laboratorium
1	0	0
2	5.45	5
3	10.7	10
4	18	15
5	23.4	20
6	26	25
7	32	30
8	35	35
9	38.5	40

Gambar 6. Grafik perbandingan pengukuran kadar air

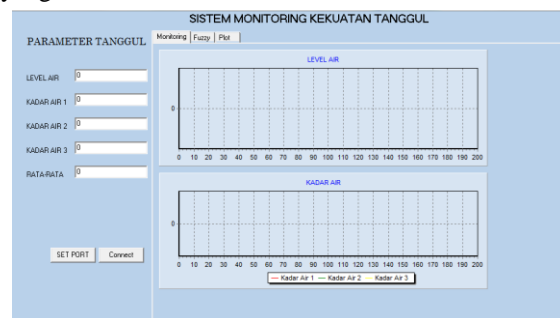
Dalam pengujian tersebut didapatkan nilai regresi R sebesar 0.994 hal ini menunjukkan bahwa antara hasil pengukuran sensor dan hasil pengukuran laboratorium terdapat hubungan dengan gradien yang positif.

4.3 Wireless Communication

Untuk mentransmisikan data mikrokontroller pada akuisisi data offline menggunakan komunikasi wireless. Perangkat komunikasi *wireless* merupakan suatu perangkat komunikasi yang digunakan untuk mengirimkan data kadar air dari sensor *node* menuju ke aplikasi sistem monitoring. Penggunaan sistem komunikasi *wireless* ini ditujukan untuk meningkatkan tingkat efisiensi dari sistem. Perangkat komunikasi *wireless* yang digunakan pada penelitiaan ini adalah modul zigbee.

Gambar 7. Layout dan Modul Wireless Xbee

Dalam penggunaannya modul komunikasi *wireless* zigbee diimplementasikan dengan menggunakan baudrate data sebesar 9600. Sedangkan untuk spesifikasi jangkauan komunikasi dari modul zigbee, untuk penggunaan indoor maka memiliki daya jangkau mencapai 30 meter. Dengan spesifikasi tersebut, penggunaan modul komunikasi zigbee telah sesuai dengan kriteria yang dibutuhkan untuk mendesain suatu sistem identifikasi dengan mengimplementasikan teknologi komukasi *wireless* dalam proses pengiriman data.

4.4 Sistem Akuisisi Data

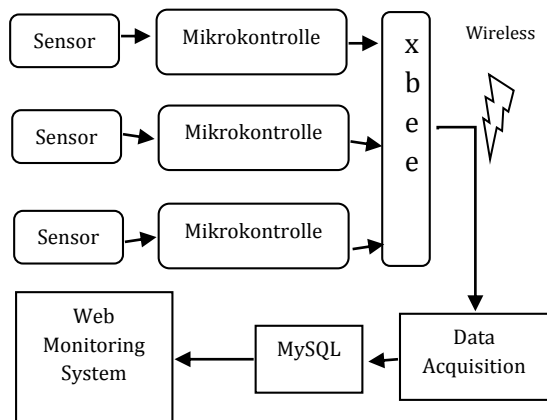
Proses sebelum terjadinya tanggul jebol akibat pengaruh volume tanggul akan dimonitor melalui kandungan air pada badan tanggul. Besarnya perubahan parameter tanah selama volume air bertambah hingga didapatkan kondisi tanggul jebol, akan menghasilkan data yang mampu menggambarkan kronologi tanggul jebol. Sistem akuisisi data yang digunakan untuk mengolah data sensor adalah melalui mikrokontroller atmega 16 yang ditransmisikan melalui wireless communication

(xbee). Data sensor tersebut akan diolah oleh aplikasi berbasis offlline untuk menghasilkan database kadar air dalam tanah. Berikut adalah tampilan akuisisi data offline sistem monitoring pada gambar 7.

Gambar 8. Sistem monitoring offline kadar air dalam tanah

Dari sistem monitoring offline tersebut akan menghasilkan data kadar air dalam tanah yang tersimpan dalam database MySQL.

4.5 Sistem Monitoring Berbasis Web

Pada sistem monitoring berbasis web ini akan menampilkan data MySQL pada aplikasi *offline*. Data yang akan ditampilkan akan menjadi sebuah informasi berkaitan dengan kekuatan tanggul yang dapat diakses pengguna melalui sebuah *browser*. Secara keseluruhan sistem yang didesain memiliki alur kerja sebagai berikut :

Gambar 8. Blok diagram sistem monitoring Web based.

Pada blok diagram diatas pengguna aplikasi dapat memanfaatkan informasi kadar air tanah melalui browser dengan tujuan mendapatkan informasi berkaitan dengan potensi bahaya yang kemungkinan terjadi.

V. KESIMPULAN

Dari rangkaian penelitian diatas dapat disimpulkan bahwa sensor kadar air yang digunakan dapat merespon perubahan kadar air dalam badan tanggul. Penggunaan xbee pada transmisi data mampu bekerja dengan baik. Sistem monitoring yang didesain diharapkan mampu memberikan informasi kadar air dalam tanah ketika proses tanggul mengalami keruntuhan. Data yang tersimpan dalam database akan menjadi sebuah acuan dalam mengambil tindakan berkaitan dengan potensi bahaya tanggul jebol.

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The Effect of Perimeter Trap Cropping Using Lemon Grass (*Andropogon nardus*) as Pest Management Improvement on Rice Paddy (*Oryza sativa* Var.IR 64) in Purwoasri, Indonesia

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Abstrak – *The aim of the research was to determine if lemon grass (Andropogon nardus) is an appropriate trap crop for the Integrated Pest Management (IPM) in the production of rice (Paddy Var. IR 64). To evaluate the perimeter trapping strategy as a pest control method, field tests were conducted in herbivores and beneficial arthropods abundance and diversity on paddy field in Purwoasri, Pasuruan, East Java. Yellow pan traps and sweep nets were applied in each 10 days during paddy growth stages (vegetative - reproductive stages) on main crop paddy (MC) and main crop with lemon grass trap crop (TCs) fields. Statistically not significant difference among the abundance of all arthropods between both fields, MC and TCs. In TCs, the abundance of herbivorous and detritivorous arthropods was differed significantly at each paddy growth stages (P=0,05 and P=0,003, respectively), but not significant different on the beneficial arthropods (predator and parasitoid). Species composition data among paddy growth stages showed that the proportion of predator species increased in generative and reproductive stages (i.e. Conochephalus longipennis, Oxyopes javanus, Chrysosoma leucopogon). Therefore, we concluded that lemon grass grown as perimeter trap crop with the main crop paddy Var. IR 64 is not a suitable control for reducing the number of herbivores, but able to increase the proportion of natural enemy arthropods.*

Keyword: Lemon grass, perimeter trap crop, integrated pest management, rice production, arthropod herbivores, natural enemy arthropods.

I. INTRODUCTION

Trap crops are composed of one or more plant species that are grown to attract a pest species in order to protect a nearby cash crop (Hokkanen, 1991). Trap crops may be manipulated in time or space to attract insects at a critical period in the phenology ofthe pest or crop, or both (Shelton and Nault, 2004). The effectiveness of the trap crop can be further improved by adding other perimeter defenses, such as border sprays or biological, mechanical, and cultural controls to form a pest management system known as "perimeter trap cropping" (PTC). Perimeter trap cropping functions by intercepting pest migration, regardless of the direction of attack. It then concentrates the pest populations in the border area, where they can be controlled, thus preserving natural enemies in the main crop (Boucher et al., 2003; Mitchell et al., 2000). Perimeter trap cropping does not work on every pest or for every crop. However, it has the potential to improve and simplify pest management on a variety of crops grown on diversified paddy field.

The genus *Andropogon* quite enough used as a trap crop plants for herbaceous plants and has another function, which prevents erosion on agricultural land. Klein et al. (2012) showed that genus *Andropogon* able to resist and reduce insect populations of Pentatomidae family. Van den Berg et al. (2000) explained that the vetifer plant (*Andropogon zizanioides*) is repellent plants for insects, that have potential as a trap crop plants applied “push-pull strategy” to concentrate *Chilo partellus* oviposition. “Push-pull strategy” to keep it away from the main crops corn, thereby reducing pest *Chilo partellus*. One of the natural substances that have the potential to be used as a trap crop citronella (*Andropogon nardus*) are able to attract flies. Additionally *Andropogon nardus* have repellent properties to aphids, grasshoppers and mites (Amalia, 2012).

In this study, we use lemon grass (*Andropogon nardus*) as a trap crop for applying ecological IPM. The trap crop planting method that is used is the perimeter trap cropping were useful as a protection from pests that may come from many or unknown direction. Perimeter trap cropping is one of the conservation management of agricultural habitats. Habitat management is becoming very important to maintain the existence of natural enemies (Perfecto et

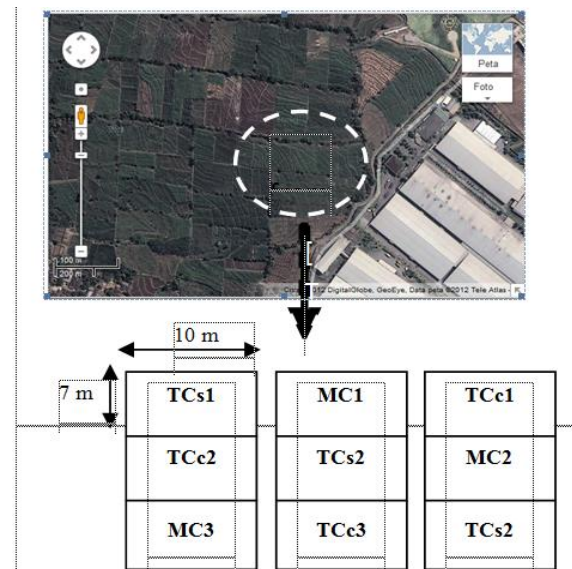
al., 2009), so the existence of herbivorous pests that potentially reduce paddy productivity can be controlled. This study was conducted to determine the effect of the application of lemon grass trap crop on the main paddy crop to the composition and diversity of herbivorous arthropods and natural enemy arthropods.

II. MATERIALS AND METHOD

In Purwoasri paddy fields, Pasuruan, we monitored the rice arthropod dynamics in a lemon grass trap crop planted surrounding rice crop (*Oryza sativa* Var. IR-64). Rice is planted twice a year alternately with tobbaco. The paddy fields are planted to paddy variety IR-64, which a dry tolerance rice variety. Paddy was planted in Main Crop fields (MC), which surrounded by lemon grass in Main Crop + Trap Crop fields (TCs). The main purpose of quantifying rice arthropod, especially herbivores dynamics and diversity, was to provide information on the perimeter trap crop using lemon grass to local farmers. They need to validate the perimeter crop method in the development of an ecological sustainable pest management.

Rice arthropods were sampled using standard insect sweep nets and yellow pan traps. Each sweep net sample was composed from 10 strokes. Yellowpan trap is a method of trapping insects trapped using yellow plastic tray which contains 1/3 water mixed with detergent. Traps installed as many as 5 pieces of each rice terraces placed as high as 3/4 of the rice plant height and left for 24 hours. Each MC (rice main crop) and TCs (rice crop with lemon grass trap crop) were sampled 10 times starting on 10 DAP (Day After Planting) until harvesting (reproductive stage). In all these treatments, samplings were done at 10 day intervals. Rice arthropods were sorted and identified on the basis of functional roles: herbivores, detritivores and beneficials arthropods (predators and parasitoids).

Habitat modification treatment with lemongrass (plot TCs1, TCs2, TCs3) planted on the edge of rice terraces as much as 2 layers thoroughly before planting paddy varieties IR-64. In the main crop plot (plot of MC1, MC2, MC3), paddy IR-64 are grown without the lemon grass as a perimeter trap crop.

Figure 1. The site map of habitat modification in paddy fields at Purwosari, Pasuruan, Indonesia. Insert : habitat modification designs, TCs 1, 2, 3 : Main crop paddy + lemon grass trap crop; MC 1, 2, 3 : Main crop paddy; TCc 1, 2, 3 : Main crop paddy + paddy ciherang trap crop.

III. RESULTS

On MC and TCs were found 85 species of arthropods, but there are differences in the number of families and species. The abundance orders in MC are Diptera (15 species from 12 families), Coleoptera (12 species from 5 families), and Araneae (10 species from 7 families). While in TCs were found mostly order Hyme-noptera (17 species from 6 families), Coleoptera (16 species from 4 families), and Araneae (12 species from 8 families).

This study was also evaluated the total composition of arthropods based on the functional role between the MC and TCs during paddy growth stages (vegetative, generative and reproductive).

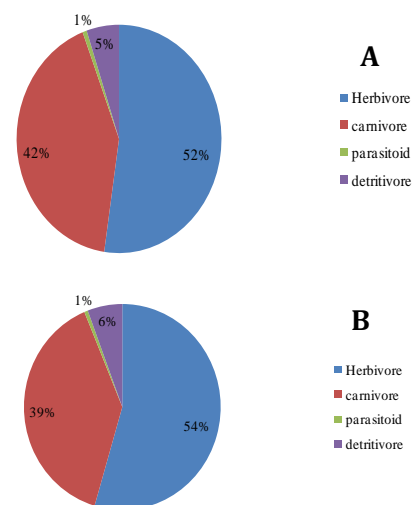



Figure 2. The composition of arthropods based on the functional role: A. Main crop paddy (MC), B.

Main crop paddy + lemon grass (TCs) at Purwosari paddy fields, Pasuruan, Indonesia.

Figure 2 shows that the number of herbivor was higher on TCs (54%) than that of MC (52%). While predator on MC was higher (42%) than that of TCs (39%). The number of detritivore slightly higher on TCs than that of MC (6% and 5%, respecively). Parasitoids show the similar abundance on both paddy fields (1%).

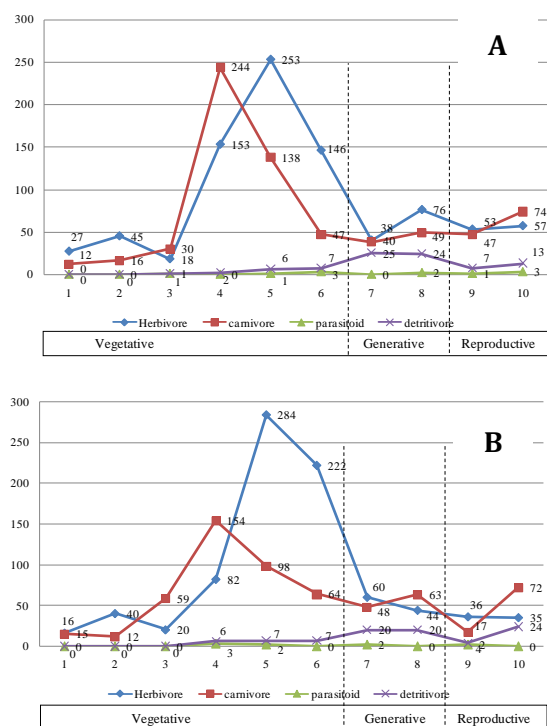



Figure 3. Abundance of arthropods based on the functional roles : A. Main crop paddy (MC), B. Main crop paddy + lemon grass (TCs) in Purwosari paddy fields, Pasuruan, Indonesia during paddy growth stages.

Figure 3 shows that the number of arthropods in both MC and TCs were changed in every stage of paddy growth.. There were changed in abundance patterns, especially on herbivores and predators. In the vegetative and reproductive stages, herbivores abundance were higher than that of the predators. During the vegetative growth stage, TCs supports high numbers of herbivores, as it shows an increase in the abundance of high (284 and 222 individuals). Probably due to the availability of the young leaves of paddy as a food resource for herbivores during the vegetative stages. In TCs, the number of predators increased following the number of herbivores in vegetative phase (154 individuals). In the reproductive stage, paddy grain growth may attract many insects. While in the reproductive stage (ripening), predators abundance were higher than of herbivores. Fluctuations in the pattern of parasitoid abundance were not clear due to their small numbers. The fluctuations in the pattern of detritivor abundance increased mainly on generative and reproductive stages.

At the both stages, the paddy leaves dried up and then felt to the ground, so that it provides food for detritivore arthropods (Vergara, 1992).

Functional role	MC			P value	MC+TC			P value
	Vegetative	Reproductive	Generative		Vegetative	Reproductive	Generative	
Herbivore	642	114	110	0,047 *	664	104	71	0,055 *
Predator	487	89	121	0,174 (ns)	402	111	89	0,232 (ns)
Parasitoid	5	2	4	0,666 (ns)	5	2	2	0,937 (ns)
Detririvore	16	49	20	0,001 **	20	40	28	0,003 *

Table 1. Comparative abundance of the functional roles of arthropods between paddy growth stages on the MC and TCs fields.

Numbers followed by asterisk are significantly different (* P<0.05; ** P<0.001) and ns (not significantly different) using T test.

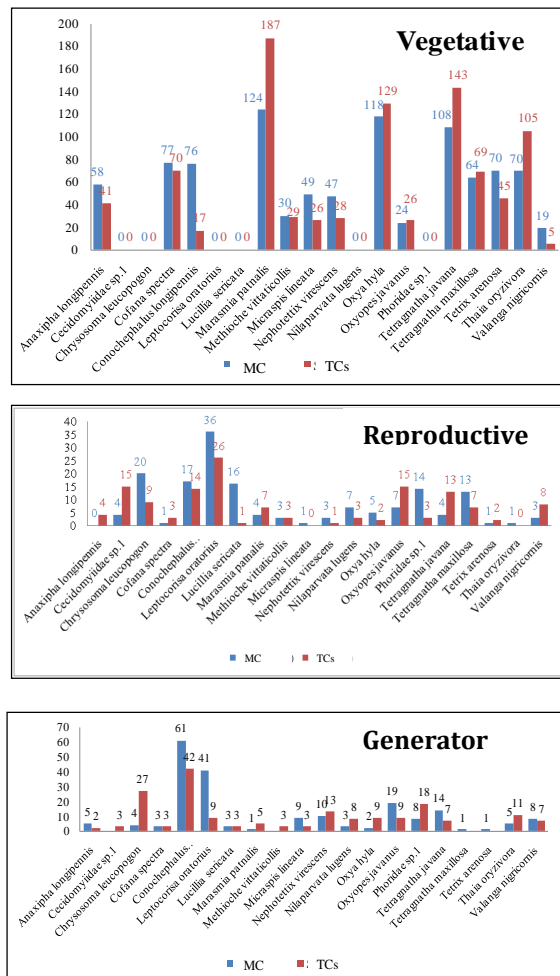
Functional role	MC			MC+TC			P value		
	Vegetative	Reproductive	Generative	Vegetative	Reproductive	Generative	Veg MC vs TCs	Rep MC vs TCs	Gen MC vs TCs
Herbivore	642	114	110	664	104	71	0,925 (ns)	0,756 (ns)	0,102 (ns)
Predator	487	89	121	402	111	89	0,553 (ns)	0,506 (ns)	0,567 (ns)
Parasitoid	5	2	4	5	2	2	1 (ns)	1 (ns)	0,596 (ns)
Detririvore	16	49	20	20	40	28	0,666 (ns)	0,549 (ns)	0,543 (ns)

Table 2. Comparative abundance of the functional roles of arthropods between two fields during in each paddy growth stage on the MC and TCs fields.

Numbers followed by letter : ns are not significantly different (P>0.05) using T test.

Table 1 shows that the number of herbivores was significantly higher among the paddy growth stages, both on MC and TCs fields (P = 0.047 and 0.055, respectively). Detritivore also showed significant differences in abundance during the growth phase of paddy on both fields (P = 0.001 and 0.003, respectively).The results shows that all functional roles in both fields have a value that is not significantly different (P>0.05). The results of T test showed that the abundance of arthropods was not influenced by the treatment, but more influenced by the growth stage of paddy, that causes the abundance of certain species (Table 2).

Figure 4. Species composition of arthropods in the three growth stages of paddy: Vegetative, Reproductive and Generative stages on Main crop paddy (MC) and Main crop paddy + lemon grass

(TCs) in Purwosari paddy fields, Pasuruan, Indonesia.

Herbivorous species that dominated both fields in vegetative stage (Fig. 4) is *Marasmia patnalis* and *Oxya hyla* which are herbivorous arthropods (family Pyralidae and Acrididae, respectively). Amalia (2012) explained that the family Pyralidae is prevalent in various crop plants both dry and wetlands. Almost all Pyralidae act as an important pest on various crops. One species of Pyralidae are *Marasmia patnalis*, which the larval stadia will be rolled or folded leaves of paddy (paddy leaffolders). *Marasmia patnalis* is potentially fitofagus as common pests found in all paddy growth stages, mainly in the vegetative stage (Litsinger et al., 1995). *Oyxa hyla* is a group of grasshoppers that have mouth appendage to chew paddy leave (Litsinger et al., 1995). In generative stage, *Leptocorisa oratorius* dominated rice which is herbivorous arthropods may potentially as a pest in paddy. Their nymph and adult insert needle-shaped mouth appendage needle into the grain. Seeds were attacked on the generative phase can be empty grains or small grains (Litsinger et al., 1995). It can be concluded that the modified habitat use lemon grass trap crop only effective against some families of herbivorous arthropods associated with the differences of paddy growth stage.

The differences in nutrient content were likely found in different stages of paddy, causing differences in the arthropod found in every paddy growth stages Species composition data among paddy growth stages shows that the proportion of predator (natural enemy) species were increased in vegetative and generative stages (Fig. 4). *Chrysosoma leucopogon*, *Oxyopes javanus* and *Conocephalus longipennis* are predator species which were increased in abundance during the vegetative and generative stages. *Chrysosoma leucopogon* are small insectivorous arthropods belongs to order Diptera (Sinclair and Cumming, 2006). This species is a small fly with big eyes and has a shiny green body, and have long legs (Litsinger et al., 1995). *Conocephalus longipennis* is a carnivorous arthropods belonging to a long aperture grasshopper group that eat eggs of herbivor insects. This species is a predator of eggs of paddy steem borer and stinky bug pest. The high abundance of this species as well as the land began to dry on generative stage. Grasshopper groups prefer a dry place to breed (Vergara, 1992). *Oxyopes javanus* is a generalist predator and direct hunter. The spider prefers drier habitats and colonizes rice fields after canopy development (Anonim, 2009).

IV. CONCLUSION

Agroecosystem management with trap crop applications using lemon grass (*Andropogon nardus*) had no effect on the composition and diversity of arthropods based on the functional role. This is supported by the non significant difference (P>0.05) between the abundance of the herbivores in main crop (MC) with lemon grass perimeter trap crop surrounding the main crop (TCs). The lemon grass trap crop is less effective on reducing the abundance of herbivorous arthropods, but able to increase the abundance proportion of natural enemy arthropods during different paddy growth stages, i.e. vegetative and reproductive stages. T test shows that the abundance of arthropods was more influenced by the growth stage of paddy, that causes the abundance of some species. High abundance of herbivorous and detritivorous arthropods were found in the vegetative TCs (P=0.055 and P=0.003, respectively). Some herbivorous species (*Marasmia patnalis* and *Oxya hyla*) was likely influenced by the presence of the lemon grass trap crop at different paddy growth stages. Some predator (natural enemy) species, i.e. *Chrysosoma leucopogon*, *Oxyopes javanus* and *Conocephalus longipennis*, were influenced during vegetative and generative stages. Ineffectiveness of habitat modification using lemon grass trap crop were related to the lemon grass growth period is longer than that of paddy. It is recommended to planting lemon grass trap crop early 2 months before planting rice on the subsequent habitat modification activities.

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29

PENGEMBANGAN SISTEM MONITORING PASANG SURUT AIR LAUT SECARA OTOMATIS DAN DIGITAL

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Abstrak – *Pada makalah ini dipaparkan hasil pengembangan sistem monitoring yang bertujuan untuk membuat alat ukur yang dapat memonitor perubahan elevasi permukaan air laut secara otomatis dan realtime. Sistem ini terdiri sensor pelampung yang digunakan untuk mendeteksi perubahan permukaan air laut. Sebuah mikrokontroler digunakan untuk mengubah adalah data analog menjadi data digital, memerintahkan sistem untuk menyimpan data ke dalam memory card dan mengirimkan data ke komputer server. Pengiriman data menggunakan media Short Message Service (SMS) dengan menggunakan modem GSM. Data yang terkirim akan diterima oleh server melalui modem penerima lalu data disimpan dalam database untuk dapat diolah dan ditampilkan pada layar display.*

Pengujian kinerja alat ukur dilakukan dengan membandingkan antara pengukuran secara manual dengan pengukuran digital dari alat ukur. Hasil pengujian menunjukkan nilai pulse yang terbaca secara digital pada alat memiliki hubungan linier dengan bacaan manual dengan korelasi sangat baik. Pengujian lain yaitu penyimpanan dan komunikasi data telah dilakukan di dalam laboratorium dengan hasil baik.

Dengan pengamatan secara real time, informasi perubahan elevasi permukaan air laut dapat diperoleh secara dini sehingga dapat digunakan untuk keperluan perencanaan lalu lintas pelayaran dan sebagai peringatan dini bila akan terjadi kondisi muka air laut ekstrim. Pengembangan alat ukur juga akan mengurangi ketergantungan pada peralatan ukur muka air dari luar negeri dan mendorong produksi alat tersebut.

Kata kunci: *monitoring*, pasang surut, otomatis, *real time*

I. LATAR BELAKANG

Dalam kegiatan perancangan bangunan pantai selalu diperlukan informasi pasang surut air laut, seperti elevasi permukaan air laut maksimum, rata-rata atau minimum. Demikian juga untuk keperluan pelayaran dan lalu lintas laut. Di beberapa pelabuhan laut dunia yang memiliki kolam pelabuhan dan alur pelayaran yang relatif dangkal dibanding dengan *draft* kapal yang akan berlabuh, informasi pasang surut secara *real time* diperlukan untuk penjadwalan kapal dengan memanfaatkan air pasang pada saat berlabuh ataupun berlayar.

Sedangkan dampak negatif yang disebabkan oleh pasang air laut adalah terjadinya banjir rob yang menggenangi dataran rendah dibeberapa kota di Pulau Jawa seperti Jakarta, Semarang dan Surabaya. Banjir rob telah mengakibatkan banyak kerugian karena menggenangi pemukiman, tambak, terganggunya lalu lintas dan aktifitas perekonomian. Salah satu usaha untuk mengurangi kerugian yang disebabkan oleh banjir rob, diperlukan informasi elevasi permukaan air laut secara *real time* agar kejadian pasang tinggi dapat diketahui secara dini. Dengan demikian maka persiapan dapat dilakukan sebelum air pasang terjadi. Pengamatan pasang surut di perairan Indonesia umumnya diamati menggunakan peralatan mekanik yaitu *Automatic Tide Recorder* (ATR) atau secara manual dengan pembacaan *peil scale*. Dibeberapa pelabuhan memang telah memiliki alat pengamatan pasang surut secara otomatis, namun jumlahnya masih sangat sedikit dan masih terkendala dengan perawatan dan pengadaan suku cadang.

Pengamatan pasang surut dengan alat ATR, elevasi muka air diperoleh dari hasil penggambaran grafik berdasarkan perubahan muka air terhadap waktu. Kendala yang dihadapi adalah masih diperlukan usaha untuk merubah data gambar grafik kedalam data pencatatan. Pencatatan dengan menggunakan kertas

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grafik juga terdapat permasalahan pada pengadaan kertas dan tinta.

Sedangkan pengamatan langsung dilakukan dengan operator/petugas dengan melihat langsung *level a*ir pada mistar skala dilokasi pengukuran dan waktu pengamatannya. Kendala yang dihadapi adalah perubahan muka air pasang surut terjadi dalam waktu cukup cepat sehingga harus diamati secara kontinyu, oleh sebab itu pengamatan secara manual dalam waktu lama tidak memungkinkan disamping juga ada kesulitan pada pengamatan malam hari.

Saat ini telah banyak dikembangkan alat-alat untuk pengamatan pasang surut secara otomatis baik yang diproduksi dari dalam negeri maupun luar negeri. Alat-alat tersebut memiliki variasi yang bermacam-macam baik dari segi metoda pengukuran, efektifitas, akurasi, harga alat, biaya operasional dan perawatan. Alat-alat produksi luar negeri biasanya memiliki akurasi baik namun biaya pengadaan, operasional dan pemeliharaannya mahal. Kendala utama bila menggunakan alat produksi luar negeri adalah jika terjadi kerusakan pada alat akan sulit untuk menemukan pihak yang bisa memperbaiki apalagi kalau harus mengganti suku cadang. Pengamatan pasang surut pada prinsip kerjanya sama dengan pengamatan muka air sungai/danau sehingga ISO 4373:2008 dapat digunakan sebagai standar untuk pengembangan peralatan pengamat pasang surut.

Ada beberapa tipe peralatan yang telah dikembangkan untuk pengamatan pasang surut, antara lain adalah sebagai berikut :

a. *Kelvin type tide gauges*, alat ini dikembangkan Lord Kelvin, di produksi dan digunakan di Inggris mulai tahun 1891. untuk mencatat perubahan pasang surut alat ini menggunakan pensil dan pegas dan kemudian dikembangkan dengan pena oleh *Geographical Survey Institute*. Kelemahan dari alat ini adalah karena menggunakan kertas maka kertas tersebut mudah mengembang dan lembab.
b. *Fuess type tide gauges*, alat ini dibuat dan mulai digunakan tahun 1963 di Jepang. Sampai tahun 1992 alat ini masih digunakan dengan beberapa modfikasi. Untuk mencegah kelembaban, kertas ditempatkan pada posisi horisontal dan diberi penutup. Sumber tenaga yang digunakan adalah listrik.
c. *GSI type tide gauge*, alat ini dikembangkan oleh *Geographical Survey Institute (GSI)* dan digunakan dari tahun 1966 sampai 1991. alat ini menggunakan gabungan elektrik mekanik hasil dari pengembangan sistem pendulum.
d. *High accuracy automatic tide gauge (personal computer type)*, alat yang dibuat oleh *Geographical Survey Institute* dan sebuah perusahaan swasta mulai digunakan pada tahun 1985. Alat ini telah memiliki memori komputer untuk menyimpan hasil pengukuran setiap 30 detik. Jaringan telepon digunakan untuk mengirimkan data lapangan ke pusat data.
e. *High resolution automatic tide gauge (data logger type*), Alat ini awalnya menggunakan komputer personal untuk mengukur dan menyimpan data pasang surut secara otomatis. Kemudian dikembangkan data logger untuk penyimpanan data dan menyelesaikan permasalahan penggunaan komputer yang rentan terhadap kelembaman dan air asin.

Gambar 1. Fuess Type Tide gauges (kiri) *dan High Resolution Automatic Tide Gauge* (kanan)

Seiring dengan perkembangan dalam bidang elektronika, instrumentasi dan telekomunikasi, alat ukur yang mudah dalam pengoperasian dan pemeliharaan serta memiliki akurasi baik dapat dikembangkan. Untuk melakukan pengamatan muka air laut secara *real time* dari jarak jauh diperlukan beberapa perangkat sebagai berikut :

1. Sensor muka air yang dapat digunakan untuk perubahan mengukur tinggi/elevasi muka air laut.
2. Perangkat media komunikasi data yang diperlukan untuk mengirim data dan menerima data pengamatan muka air laut.
3. Komputer server dan data base yang diperlukan untuk mengolah dan menyampaikan data/informasi pasang surut.

Sensor yang dapat digunakan untuk mengamati muka air ada beberapa macam, seperti sensor tekanan, sensor pelampung dan sensor ultrasonik. *Sensor-sensor* tersebut masing-masing memiliki kelebihan dan kelemahan.

Sensor pelampung memiliki akurasi cukup tinggi dan mudah dikembangkan. Sensor ini bekerja berdasarkan prinsip bahwa pergerakan naik atau turun

muka air laut menyebabkan pelampung yang mengapung di permukaan air ikut bergerak. Pelampung dihubungkan dengan tali ke pemberat dan tali tersebut di lilitkan pada *Pulley*. Pergerakan pelampung akibat pasang surut air laut menyebabkan berputarnya *Pulley*, perputaran *Pulley* tersebut menggerakkan *pulse* yang dapat diubah kedalam nilai tinggi muka air.

Penggunaan *sensor* pelampung memiliki kelebihan mudah diadaptasikan pada alat ukur yang ada saat ini yaitu ATR maupun AWLR karena memiliki persamaan prinsip sehingga hanya diperlukan perubahan data *analog* ke data digital. Sistem operasi pelampung sangat mudah dipahami. Banyak macam peralatan elektronik yang dapat digunakan dalam sistem pelampung seperti *encoders*, *potentiometers*, *Linear variable differential transformers* atau *synchros*. Kebanyakan *encoder* yang digunakan pada sensor memiliki kestabilan terhadap perubahan suhu. Muka air yang diamati cukup stabil karena terlindung dalam tabung/pipa. Sedangkan kelemahan dari sensor pelampung adalah membutuhkan biaya untuk pembuatan konstruksi dan tabung/pipa/sumuran dan tali pelampung bisa terlepas dari *Pulley*.

Pengamatan muka air dengan menggunakan sensor ultrasonik memiliki keterbatasan yaitu sensor sangat sensitif pada getaran dan suara sehingga akurasi pengukuran dapat menurun. Sedangkan sensor tekanan sangat dipengaruhi oleh konsentrasi dan endapan sedimen yang dapat mempengaruhi massa jenis dari air.

Komunikasi data merupakan bagian dari teknologi informasi, dimana perangkat *transmitter* melakukan pengiriman data berupa informasi yang disajikan oleh isyarat *digital biner* terhadap *reciever* atau terminal. Media komunikasi data untuk telemetri yang dapat digunakan saat ini adalah GEO *Satellite*, Gelombang Radio, *Spread Spectrum*, *Celluler*, *Bluetooth Wireless*. Masing-masing media komunikasi tersebut di atas memiliki jangkauan komunikasi yang berbeda-beda (Lasminto, 2008).

Media seluler berkembang sangat pesat baik kualitas maupun luas jaringannya sehingga jarak bukan merupakan kendala lagi. Marcell Gautschi dalam suatu jurnalnya tentang "*Autonomous Measuring System With Remote Transmitioni*" yang ada di site www.keller-duck.com menjelaskan tentang perlu adanya otomatisasi sistem pengukuran dan transmisi data yang akurat dan cepat. Pemanfaatan untuk pengiriman data digunakan fasilitas yang ada di *mobile-phone* yaitu dengan fasilitas GSM (*Global System for Mobile Comminication*) sebagai pengiriman data yang cepat dan murah. Didalam jurnalnya dibahas tentang sistem pengukuran otomatis untuk mengukur tinggi muka air sungai sebagai monitoring ketinggian air sungai. Jaringan fasilitas SMS (*Short Message Service*) digunakan sebagai media komunikasi monitoring level air sungai. Kelebihan penggunaan jaringan seluler sebagai telemetri adalah tidak perlu untuk membuat antena pemancar dan penerima sendiri, mudah untuk melakukan pengesetan, biaya perawatan rendah, sistem komunikasi dua arah dan informasi dapat diberikan melalui *pager*, internet, *Handphone* dll. Sedangkan kelemahannya adalah peralatan harus berada dalam area yang tercover sinyal jaringan, memerlukan biaya *service*/operasional yang sangat tergantung pada lokasi dan *provider* yng digunakan, sangat tergantung pada *provider* yang digunakan misalnya *coverage area* dan *communication protocol*, *k*oneksi dapat terganggu pada saat aktivitas transmisi mengalami beban puncak.

Dalam sistem telemetri diperlukan perangkat penerima data, pengolah dan penyimpan data. Perangkat ini terdiri dari unit penerima data (*reciever*), komputer *server* dan *database*. Unit *reciever* berfungsi sebagai penerima data, komputer *server* merupakan perangkat keras untuk penyimpanan, pengolahan dan pemakaian data. Operasi dalam komputer berhubungan dengan pengolahan data dan sebagian besar program yang berhubungan dengan operasi data dilakukan dengan menggunakan database (Suyanto dkk, 2008). D*atabase* digunakan sebagai perangkat lunak dalam manajemen data.

METODOLOGI STUDI

Pada penelitian ini dilakukan perancangan dan pengujian sistem pemantauan pasang surut air laut secara otomatis dan *real time* dengan tujuan untuk memperoleh sebuah sistem pengukuran yang memiliki reliabilitas tinggi, mudah dalam penggunaan dan perawatan, serta menggunakan material dengan muatan lokal.

Penelitian diawali dengan melakukan review terhadap hasil desain penelitian terdahulu dan penelitian lain yang berkaitan. Tahap berikutnya adalah mendesain sensor pencatat muka air, jaringan komunikasi data, data base dan sistem informasi serta dilanjutkan dengan pembuatan dan perakitan sensor muka air, mikrokontroler, membuat software untuk penyimpanan, pengiriman dan penerimaan data. *Hardware* dan *software* yang telah dibuat diintegrasikan dan tahap akhir adalah menguji masing-masing bagian dan sistem secara keseluruhan

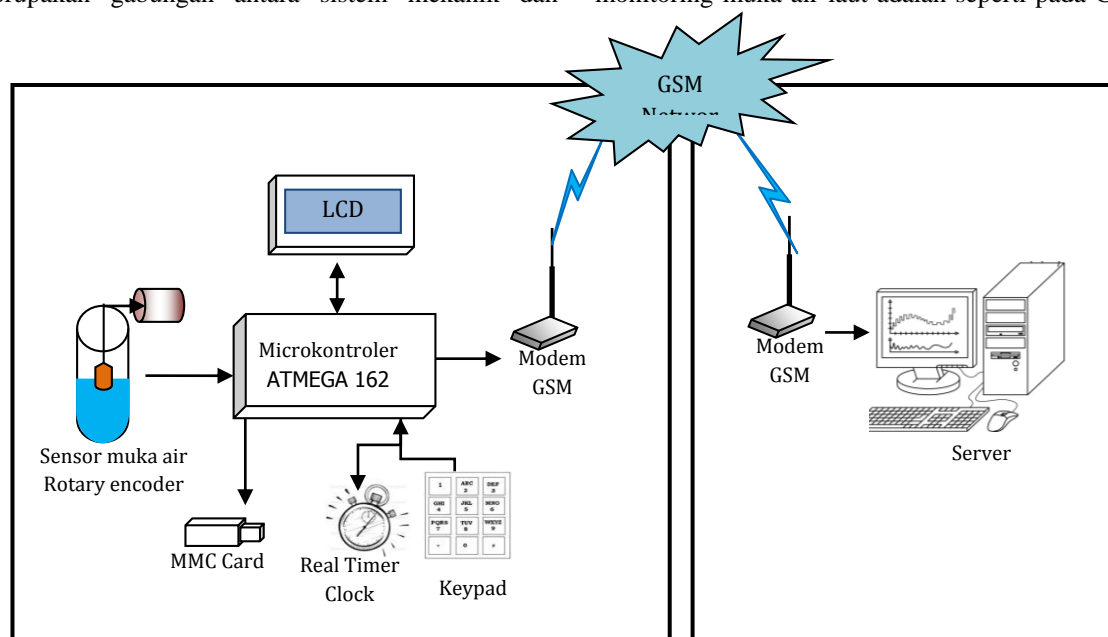
Tahapan kegiatan pembuatan *prototype* alat pengamatan pasang surut secara otomatis dimulai dengan melakukan review terhadap hasil desain penelitian terdahulu dan penelitian lain yang berkaitan. Kemudian dilakukan survey lokasi untuk menentukan lokasi pemasangan sensor pencatat data dan muka air laut. Survey lokasi dimaksudkan untuk mendapatkan informasi kondisi lokasi pemasangan alat. Informasi tersebut diantaranya adalah lokasi alat, konstruksi yang diperlukan, keamanan alat dan sinyal komunikasi. Kegiatan selanjutnya adalah mendesian sensor pencatat muka air, jaringan komunikasi, data

base dan sistem informasi. Pada proses desain dibuat spesifikasi desain dengan melakukan penyesuaian dan penyempurnaan rancangan sistem monitoring muka air yang dihasilkan oleh studi terdahulu. Tahap selanjutnya adalah pembuatan/perakitan *hardware* dan *software*. *Hardware* terdiri dari sensor pengukur muka air, mikrokontroler, modem pengirim dan penerima serta komputer server. Sedangkan *software* terdiri dari program untuk akuisisi data, program data logger, program pengiriman dan penerima data serta program data base. Masing-masing hardware dan software diuji coba apakah sudah dapat bekerja dengan baik. Setelah masing-masing *hardware* dan *software* siap dan teruji maka dilakukan pengintegrasian untuk menjadi sebuah sistem pengukuran. Pengujian kembali dilakukan untuk keseluruhan sistem apakah masing-masing komponen dapat bekerja dengan baik dan dapat berinteraksi dengan komponen lain. Tahap terkahir adalah melakukan evaluasi kinerja masing-masing komponen dan sistem secara keseluruhan.

HASIL STUDI DAN PEMBAHASAN

Konsep sistem monitoring muka air laut untuk peringatan dini banjir rob dan tsunami merupakan sebuah sistem yang secara otomatis dan *real time* mengukur tinggi muka air laut dan menyimpan hasil pengukuran tersebut dalan sebuah data *logger* serta mengirimkannya ke sebuah komputer *server* yang berada pada kantor pengamatan.

Prototype alat monitoring muka air laut yang dikembangkan memiliki diagram fungsional seperti pada Gambar 2. Sistem ini terbagi atas dua sub sistem utama yaitu sistem pengukuran muka air laut dan sistem *server*. Sistem pengukuran muka air laut merupakan gabungan antara sistem mekanik dan sistem elektronik yang dipasang dilapangan, dimana sistem ini akan melakukan pengukuran secara kontinyu ketinggian muka air laut dan menyimpannya dalam sebuah data *logger*. Selain disimpan dalam sebuah data *logger*, hasil pengukuran tersebut dikirim ke server menggunakan media wireless yaitu jaringan GSM dengan media *Short Message Service* (SMS). Sistem server merupakan sistem yang terdiri atas penerima data berbasis wireless dan sebuah komputer. Sistem ini berada pada kantor pemantauan yang letaknya terdekat dengan sistem pengukuran muka air laut. Pada sistem ini data – data yang diterima dari hasil pengukuran akan ditampilkan melalui *Human Machine Interface* (HMI). Di HMI ini data tersebut akan direpresentasikan secara visual, sehingga akan kelihatan dengan mudah kondisi yang ada dilapangan

Sensor level muka air pada penelitian ini menggunakan sebuah pelampung yang dikaitkan pada sebuah *pully* yang terhubung dengan *rotary encoder*, dimana jika pelampung bergerak naik atau turun mengikuti muka air laut maka *rotary encoder* juga ikut berputar. Putaran dari *rotary encoder* akan mengeluarkan *pulse* yang dapat dibaca oleh *mikrokontroler*. Pada gambar tersebut *pully* besar dan kecil dihubungkan dengan sebuah tali dimana kedua ujung tali diberi beban berupa pelampung dan pemberat. *Pully* kecil digunakan untuk menjamin agar terjadi selip di *pully* besar sehingga setiap perubahan pelampung walaupun kecil akan tetap memutar *pully* besar. Pelampung tersebut akan bergerak naik turun sesuai ketinggian muka air, sedangkan pemberat berfungsi untuk menegangkan tali sehingga tali tidak kendor. *Rotary encoder* dipasang satu poros dengan sumbu pully besar, sehingga jika pully besar berputar maka *rotary encoder* ikut berputar. Desain alat monitoring muka air laut adalah seperti pada Gambar

Gambar 2. Diagram fungsional sistem monitoring muka air laut.

3 berikut.

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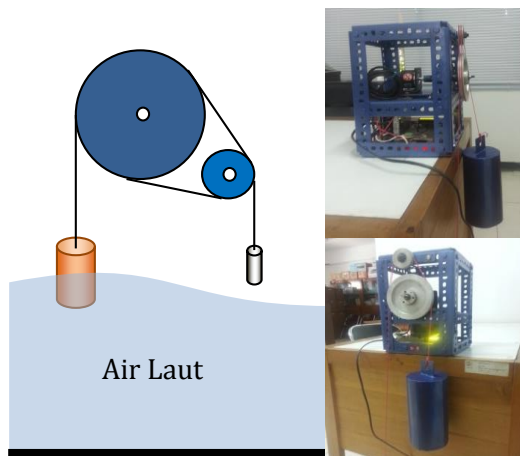
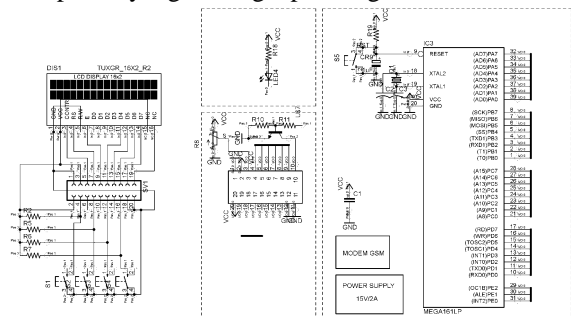

Gambar 3 Prinsip dasar pengukuran pasang surut (kiri) dan hasil desain (kanan)

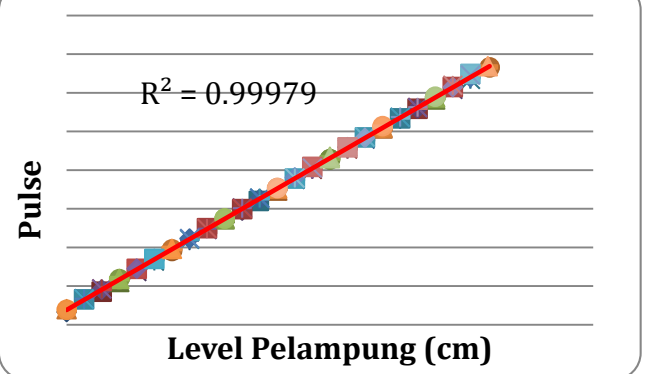
Diameter *pully* besar didesain dengan ukuran 12 cm, karena itu keliling pully besar adalah 37,7 cm. Dalam satu putaran rotary encoder mengeluarkan pulsa sebanyak 1000 *pulse* sehingga satu *pulse output rotary encoder* mencerminkan perubahan *level* sebesar 37,7/1000= 0,0377 cm. Sehingga ketelitian alat ini adalah 0,377 mm. *Pully*, pelampung, pemberat dan as *rotary encoder* yang telah di desain kemudian di buat yang hasilnya seperti pada foto pada gambar berikut

Gambar 4 Pully dan rotary encoder (atas), pelampung dan pemberat (bawah)

Mikrokontroler merupakan pusat pengontrol dan data dari sebuah sistem. Diantara berbagai macam keluarga mikrokontroler, mikrokontroler 8051 adalah yang paling populer dan fleksibel (Ahluwalia, 1995). Dalam penelitian ini mikrokontroler yang digunakan adalah jenis mikrokontroler 8 bit yaitu ATMEGA 162. Mikrokontroler ini akan melakukan perhitungan terhadap pulsa yang keluar dari rotary encoder dimana jumlah pulsa yang keluar dari *rotary encoder* mencerminkan level muka air laut. Selain menghitung pulsa mikrokontroler juga akan menyimpan data perhitungan tersebut dalam sebuah data logger, dimana dalam penelitian ini data logger yang digunakan berupa *Multi Media Card* (MMC). MMC yang dipasang dapat menampung data hingga 16 *Giga byte*. Mikrokontroler juga terhubung dengan jaringan komunikasi berbasis wireless yaitu modem GSM. Melalui jalur ini data dari sistem pengukur dikirim ke server menggunakan media *Short Message Service* (SMS). Data hasil pengukuran dan segala proses yang ada di sistem pengukur ini ditampilkan pada local display berupa LCD 16x2. Adapun rangkaian mikrokontroler dan hasil implementasi rangkian terlihat pada Gambar 5.

Gambar 5 Skematik (kiri) dan rangkaian (kanan) mikrokontroler.

Sistem *server* merupakan sistem yang dipasang di kantor pemantau. Sistem ini terdiri atas sebuah komputer yang dilengkapi dengan sebuah modem

penerima GSM. Perangkat lunak untuk komunikasi data adalah program pengiriman dan penerimaan SMS dikembangkan dari program aplikasi SMS yang dibuat oleh Bustam Khang (2002). Sistem server terhubung dengan sistem *database*, sehingga kita dapat melihat *historical data* hasil pengukuran hingga beberapa tahun yang lalu. Program komputer Delphi adalah salah satu program yang handal untuk pembuatan data base (Rumono, 2004).

Gambar 6 Hasil pengujian pengukuran level muka air

laut.

Dari hasil pengujian di lapangan terkait ketelitian alat dalam mengukur muka air laut diperoleh data seperti yang terlihat pada Gambar 6. Pada gambar tersebut terlihat hubungan linier antara perubahan *pulse* dan perubahan tinggi muka air. Korelasi dari bilai bacaan *pulse* dan perubahan tinggi muka air sangat baik.

KESIMPULAN DAN REKOMENDASI

Kesimpulan

1. Hasil dari penelitian ini adalah sebuah prototipe sistem monitoring elevasi permukaan air laut secara yang bekerja secara otomatis dan real time. Sistem ini terdiri dari tiga bagian utama yaitu pertama pelampung yang digunakan untuk mendeteksi perubahan permukaan air laut. Bagian kedua adalah sebuah mikrokontroler yang digunakan untuk mengubah adalah data *analog* menjadi data digital, memerintahkan sistem untuk menyimpan data ke dalam *memory card* dan mengirimkan data ke komputer *server*. Pengiriman data melalui media *Short Message Service* (SMS) dengan menggunakan *modem* GSM. Bagian ketiga adalah komputer *server* yang digunakan untuk menyimpan, mengolah dan menampilkan data berupa elevasi permukaan air laut.
2. Pengujian kinerja alat ukur dilakukan dengan membandingkan antara pengukuran manual dengan pengukuran digital dari alat ukur. Hasil pengujian menunjukkan nilai *pulse* yang terbaca secara digital pada alat memiliki hubungan linier dengan bacaan manual dengan korelasi sangat baik. Pengujian lain yaitu penyimpanan dan komunikasi data telah dilakukan di dalam laboratorium dengan hasil baik.

Rekomendasi

Untuk mendapat hasil desain sistem monitoring yang lebih baik maka perlu dilakukan pengujian dalam jangka waktu lebih lama di lapangan. Pengujian tersebut meliputi uji keandalan (realibity test), uji keamanan (safety test) dan uji fungsi (function test).

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30 Vulnerability Modelling to Improve Assessment Process on Community Vulnerability

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Abstract – *Most vulnerability assessment is conducted by assessing geographical areas based on their vulnerability levels with the aim of using those results for applied public policies on disaster risk management (DRM). This assessment process has been criticised as an oversimplification and because it fails to integrate vulnerability with other DRM concepts. This paper discusses the limitations of current approaches to vulnerability assessment and identifies key directions for a future research agenda to support better assessment processes at the community scale. To date, vulnerability assessment has failed to recognise the dynamic and systemic character of community vulnerability and the importance of integrating concepts of vulnerability, resilience and adaptation within the assessment process. This means it is inadequate for the purpose of assessing future vulnerability using quantitative modelling. In consequence, public policy often relies solely on assessments of current vulnerability levels for decision-making. This paper argues the need for an assessment process using vulnerability modelling. Modelling is able to emphasise characteristics of community vulnerability, assess future vulnerability, and quantitatively evaluate adaptations for specific scenarios. It integrates vulnerability with the related concepts of resilience and adaptation. As a result, this type of assessment offers a better framework for supporting more proactive public policies to reduce community vulnerability to disaster.*

Peer-review under responsibility of the Cities International Seminar Committee.

Keywords: *vulnerability, dynamic system, adaptation, evaluation, community, resilience and scenario modelling.*

I. INTRODUCTION

As an integral part of disaster risk management (DRM), the vulnerability concept has a major role to play in enhancing community capacity to respond to a particular hazard. Appreciation of the importance of DRM has increased greatly due to significant losses from disastrous events such as the Southeast Asia Tsunami 2004, the Haiti earthquake 2010 and Pakistan floods in 2010. Understanding of the concept has developed significantly since its early development in the 1980s (Gabor & Griffith,1980) based on demography and geography perspectives. It is now a multidisciplinary approach (Marandola & Hogan,2006); however, the vulnerability concept is still underdeveloped in certain respects, particularly in relation to assessment processes (Cutter, 1996; Adger et al.,2004; Adger,2006; Rygel et al.,2006; Barnett et al.,2008). Much research on vulnerability has focused on mapping regions and communities that are highly vulnerable to disasters, however this approach fails to account for the dynamic and systemic characteristics of 'community'. Some critics have argued the need to expand vulnerability research beyond the assessment of the level of vulnerability in a particular case study or region to develop predictive tools to inform policy and planning (Adger et al.,2004; Adger, 2006;Nicholls et al., 2008). However such tools require further clarification of the vulnerability concept in DRM. The review of vulnerability literature provided here aims to clarify the concept and identify key directions for a

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future research agenda to support more predictive assessment processes at the community scale.

II. METHODS

A thematic literature review is employed to emphasize the complexity of the vulnerability literature and examine how vulnerability is understood within different bodies of research, particularly in the literature on vulnerability, resilience, and adaptation.Through this process, key dimensions of vulnerability are identified and significant gaps in current understanding of the concept are highlighted in order to suggest guidelines for a future research agenda.

In identifying the gaps in vulnerability assessment and modelling, vulnerability research has been assessed for its strengths and weaknesses based on the six themes identified in Figure 1. The discussion of gaps in the vulnerability literature draws on approaches such as single and multidiscipline, single and multi hazards and before or after disaster events. Then, the discussion also continues to integrate it with other concepts beyond vulnerability such as resilience, adaptation and social capital. Afterwards, the vulnerability literature gaps are grouped in terms of their value for developing assessment processes and further research relevant to scenario modelling. Finally, some suggestions are made based on the gaps to propose a new framework for future vulnerability assessment and modelling research.

III. FINDINGS AND DISCUSSION

3.1 Framing Vulnerability Assessment

Equations and formula should be typed in Mathtype, and numbered consecutively with Arabic numerals in parentheses on the right hand side of the page (if referred to explicitly in the text). They should also be separated from the surrounding text by one space.

Since the early 1980s, the concept of vulnerability has been discussed across many disciplines, including demography, geography, human ecology, economics, anthropology and psychology (Hogan &Marandola 2006; Adger 2006). It has been approached from both natural science perspectives (such as engineering and natural processes) and social science perspectives (Robert et al. 2009). Table 1presents a range of perspectives, which are relevant in framing research on vulnerability assessment.

Perspective on vulnerability	References
Demography	Armas (2008).
Urban infrastructures	Pitilakis (2006).
Risk management	Villagran de Leon (2006).
General social science	Adger &Kelly (1999); Bankoff et al. (2004); Dwyer et al.(2006).
Environment management, science	Luers et al. (2003);Messner &Meyer (2006); Nicholls et al. (2008);Preston et al. (2008); Barnett et al. (2008).
Socio-economic modelling	Dwyer et al. (2004);Brenkert & Malone (2005);Rygel et al. (2006); Ionescu et al. (2009).
Development studies	Cannon (2008).
Socio-political	Carina &Keskitalo (2009).
Geography , human geography	Cutter (1996);Clark et al. (1998);Weichselgartner (2001); Cutter et al. (2003); Smit & Wandel (2006);Downing &Patwardhan (2004); Marandola &Hogan (2006); Cutter &Finch (2008); Cutter et al. (2008); Marfai & King (2008).
Sociology	Gillespie et al. (1993).
Engineers	Odeh (2002).
Public policy	Sharma &Patwardhan (2008).

Table 1. Some Relevant Perspectives and References in Vulnerability Assessment Research

Clarity on the vulnerability concept is important as there have been different interpretations of some of its basic terminology between researchers working in different disciplinary traditions (Cutter1996; Weichselgartner 2001). Adger (2006) argues that the variety of vulnerability interpretations indicate the importance of the concept across different disciplines and consequently should be understood as a strength rather than a weakness. However, greater definitional clarity is needed to progress research in areas requiring systemic approaches such as vulnerability assessment (Cannon, 2008; Ionescu et al. 2009), a key concern of this paper.

The concept of vulnerability is multi-layered as it includes the responses of individuals, groups of individuals and social networks to hazards. Adger & Kelly (1999) suggest that the vulnerability level reflects the state or situation of the individuals, groups or communities affected by a disaster. Moreover, Dwyer et al. (2004); Villagran de Leon (2006) suggest a broader range of research subject matter for vulnerability studies drawing on the terminology of

human communities. In fact, vulnerability research has been focused on assessing individual's and groups of individuals' responses to any hazards (e.g. Odeh 2002; Armas 2008;). Therefore, any vulnerability assessment should extend beyond individuals to larger groups of people. The larger groups of people should include groups of people within the community and also the relation between groups within and outside of the community (community network) that are stressed in the social capital literature (e.g. Putnam 2000; Woolcock &Narayan 2000; Reimer et al.2008; Wagner & Fernandez-Gimenez 2008).

Since community is a central concern in much vulnerability literature, consideration of dynamic-systemic community characteristics is important. Bankoff et al. (2004) suggest that communities are dynamic and systemic entities. Dynamic means that characteristics may change when there is a change in specific factors over time, while systemic means all the subsystems within a community (factors) are interlinked and interact in influencing the final vulnerability level. Research by Cutter &Finch (2008) predicts future vulnerability levels based on the dynamic aspects of community vulnerability, as the level is changing from time to time, while other researchers have focused on the effect of dynamic vulnerability factors on the current vulnerability level (e.g. Odeh 2002; Armas 2008; Marfai &King 2008;). In addition,Gillespie et al. (1993) hasapproached the systemic aspect of community by examining the network of organizations contributing to community disaster preparedness.

Considering the points outlined above, any assessment of vulnerability should begin with clarification of terms and definitions. Since there is no universally accepted definition of vulnerability, vulnerability within this paper will be defined as: the dynamic and systemic performances of community capacities to cope with specific hazards in time and space. This definition is drawn from the dimensions discussed above that are summarised in Table 2.

Table 2. Four Dimensions of Vulnerability

Dimensions Of Vulnerability	Supporting Literature
Focuses on specific communities that are exposed to certain hazards (context specific).	**Cutter et al. 2003; Schroter et al. 2005; Brenkert &Malone 2005; Messner &Meyer 2006; Sharma &Patwardhan 2008; Preston et al. 2008.**
Covers three levels of society - individuals, groups of people and social networks - associated with a specific community.	**Adger &Kelly1999; Dwyer et al. 2004; Villagran de Leon 2006; Carina & Keskitalo 2009 urge on a need broader context of subject while Putnam 2000; Woolcock &Narayan 2000 stress a power of social network in community.**
Vulnerability also reflects the community's capacity to reduce the impacts of certain hazards. This capacity can reduce the current vulnerability level, leading to lower future vulnerability levels.	**Dow 1992; Adger &Kelly 1999; Downing et al. 2001; Dwyer et al. 2004; Pitilakis et al. 2006; Villagran de Leon 2006;Armas 2008.**
The level of a community's vulnerability changes as a consequence of dynamic and systemic interaction among factors as a consequence of community characteristics.	**Gillespie et al. 1993;Odeh 2002; Bankoff et al. 2004; Cutter &Finch 2008; Armas 2008; Marfai &King 2008.**

3.2 Vulnerability Assessments: Gaps in the Literature

While various authors have assessed the level of vulnerability based on a range of factors, the basis they use for choosing these factors is often not clearly described (first gap). Furthermore, the selection of factors is rarely linked to the characteristics or dimensions of community vulnerability. This problem is highlighted by Alwang et al. (2001); Adger et al. (2004); Downing & Patwardhan (2004) who argue the need for clearer elaboration of the factor selection process. Even though some research has considered vulnerability factors from a range of disciplinary perspectives, the selected factors have a weak correlation with the core characteristics of the vulnerability definition as outlined in Table 2 (e.g. Armas 2008; Odeh 2008.). Therefore, linking these dimensions of vulnerability to the factor selection process is important.

There is a need to assess the effectiveness of adaptations in reducing vulnerability, preferably using quantitative approaches that evaluate different scenarios. To accommodate a quantitative approach, vulnerability needs to be specified into several measurable indicators, such as in Brenkert &Malone (2005); Armas (2008). The indicators are a set of subcomponents which reflect vulnerability performance within a community. The indicators are different tovulnerability factors which represent the causes of vulnerability for a community. Future research should focus on scenario modelling to identify the most effective adaptation measures to reduce future vulnerability to disasters.

3.3. Bridging the Literature Gaps in Reducing Future Vulnerability Level

The gap is in clearly identifying the dimensions of vulnerability and how aspects of the community context should inform the factor selection process. The process of selectingrelevant factors can begin by making a long-list of factors from previous relevant research. Afterwards, the factors can be grouped based on different social scales from individuals to community a larger group and a multidisciplinary approach then used to assess their relevance to a specific case study location. The result can be a short-list of preliminary vulnerability factors (e.g. disadvantaged people, emergency facilities and utilities, external support andnumber of residents).
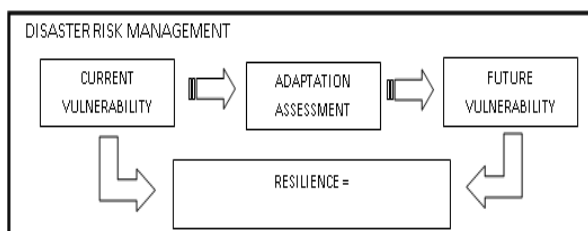
Fig. 1. Integration of the vulnerability concept with the concepts of adaptation and resilience

Finally, the preliminary factors should be verified by some key stakeholders using a delphi process or focus group discussion to select the relevant final factors for vulnerability assessment in each case study. This verification is important to ensure the context specific value of vulnerability assessment.

The lack of consideration of two-way influences on vulnerability factors, can be represented as a process of adding or overlaying various vulnerability factors as independent variables (vulnerability factors) which
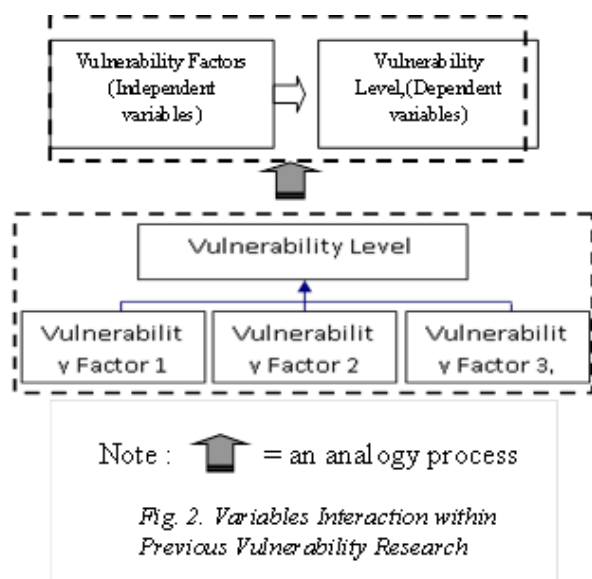
Fig. 2. Variables Interaction within Previous Vulnerability Research

influence dependent variables (vulnerability level or indicators) as shown in Figure 1.

In Section B, one of the vulnerability dimensions identified was a dynamic-systemic situation that should be reflected in the interactions among factors, adaptations and indicators. Therefore, the interaction cannot be as in Figure 2, but it should reflect dynamic and systemic situation as illustrated in Figure 5 below. In responding to these community characteristics, a dynamic system analysis can be utilized to model or simplify the community dynamic and represent systemic relationships among factors, adaptations and indicators (Sterman 2001). Moreover, in predicting levels of vulnerability, the analysis can also run certain models (based on some scenarios of adaptation) to produce various future vulnerability levels.
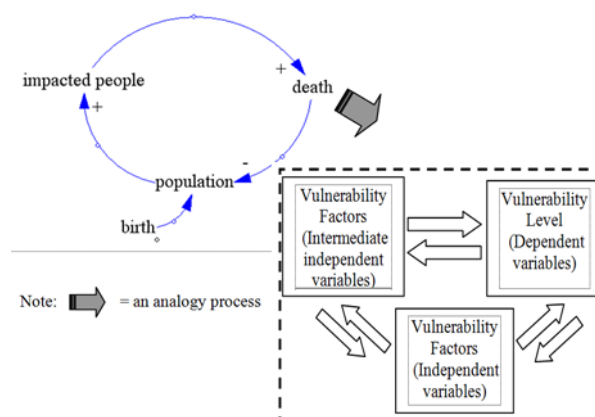
Fig. 3 Variables Interaction for Future Vulnerability Research

Since there are then some predicted levels for future vulnerability, comparison among them responds to the fifth gap, the need for assessments to evaluate the effectiveness of adaptations. The quantitative approach in dynamic system analysis could give a ranking system based on these comparisons. The rank will sort the future levels from highest to the lowest. Therefore, the most effective adaptation can be distinguished from the lowest future vulnerability level after applying certain scenarios through the modelling process. This selection process can provide a rationale for policy-making.

The number of victims, damage losses and the period of time for recovery can be utilized to respond to the last (sixth) gap around the need for measurable vulnerability indicators. Number of victims and damage losses indicators can be seen as various applications of impact assessment post hazard events. Those two kinds of valuation can also represent the vulnerability level based on the assumption of the hazards as a given variable (constant). Moreover, the period of time is drawn from the concept of resilience (the ability of community to “bounce back” (recover) after an event as in Mileti & Peek 2002; Paton et al.

2003 cited in Ronan & Johnston 2005). Those three kinds of measurements can also be set as major step to prepare a community facing negative events, as suggested by Ronan and Johnston (2005). Preparation itself can be made by taking adaptations to reduce the possibility of fatalities, damage losses and a long period of recovery.

In Summary, some points for a proposed vulnerability research framework are set out in Table 3 below. These points can provide a rational basis for proposing vulnerability modelling using a system dynamic analysis.

Table 3. Literature Gaps and Basic Principles for Future Research

No	Previous Research Results	Literature Gaps	Basic Principles For Future Research
1	Vulnerability factors have been discussed widely (e.g. Odeh 2002; Armas 2008).	A need for clarity about the process for vulnerability factor selection explaining its dimensions (e.g. Alwang et al. 2001; Adger et al. 2004; Downing &Patwardhan 2004).	**Factor selection should reflect the three layers of society, specific context and multidisciplinary approach.**
2	Vulnerability research often finishes with the assessing vulnerability levels (e.g. Gabor & Griffith 1980; Odeh 2002; Rygel et al. 2006; Armas 2008).	There is urgency in integrating between discussing causal vulnerability factors and stakeholders actions in vulnerability assessment process.	**The assessment process can also be expanded from assessing the levels to evaluating critical factors and stakeholders' actions.**
3	Factor interaction occurs in overlaying/addition process to find final level (e.g. Gabor & Griffith 1980; Odeh 2002; Rygel et al. 2006 and Armas 2008).	The factors are interdependent and interact to reflect dynamic and systemic characteristics.	**The use of system dynamic analysis can represent dynamic and systemic community characteristics.**
4	Research focus on current vulnerability level (e.g. Clark et al. 1998; Odeh 2002; Armas 2008). Conversely, Little research attempts to predict future vulnerability levels (such as in; Marfai &King 2008; Cutter &Finch 2008;Nicholls et al. 2008).	A need to expand the analysis to future vulnerability and connect it with other concepts within DRM. A need to accommodate core characteristics of community when expanding vulnerability research.	**Discussing the difference between current and future vulnerability levels links vulnerability with concepts of resilience and adaptation. Moreover, linking those concepts should accommodate the dynamic and systemic characteristics of community.**
5	Research focus on assessing vulnerability levels (e.g. Gabor & Griffith 1980; Odeh 2002; Brenkert &Malone 2005; Rygel et al. 2006; Armas 2008; Preston et al. 2008).	The research can be expanded to evaluation of adaptation (Adger et al. 2004)	**Linking the concepts of vulnerability, resilience, and adaptation can help to direct adaptation evaluation.**
6	**Little research uses vulnerability indicators to specify the broad concept of vulnerability (e.g. Brenkert & Malone 2005; Armas 2008).**	**The specification of vulnerability indicators should be designed to highlight the results of adaptation measures.**	**Effective adaptation can be revealed by the number of victims, damage losses and recovery process.**

3.4. Conclusion

This paper identifies gaps in the vulnerability literature and presents an approach to respond to these gaps, specifically from the perspective of improving systematic assessment processes. Since the vulnerability concept draws from a range of disciplines and there are diverse definitions, the dimensions of vulnerability were clarified first, then utilized as one of the criteria for analysing the gaps in the literature. A wide range of literature within and beyond vulnerability was then reviewed, particularly that which engages with concepts of resilience, adaptation and community in the context of vulnerability to disasters. The major gaps identified in

the literature provide a basis for framing a future research agenda.

Based on these gaps, the following three main areasare proposed for future research in vulnerability modelling:

- The modelling should consider all community layers (individual, groups of people and social networks) and shouldfocus on community case studies where vulnerability dimensions can be characterised at the community scale. It is a reflectionof vulnerability dimensions.
- The context specificdimension of vulnerability modelling outlined in the first point is particularly important for selecting relevant factors and identifying interactions among them. The selection process should reflect the layers of community and be context specific in terms of hazard type, while the interaction should reflect the dynamic and systemic nature of the community. The end result of modelling should go beyond assessment of existing vulnerability levelsto develop predictive capacity. This requiresa capacity to evaluate scenarios of adaptation to provide a predictive tool for reducing the level of future vulnerability.
- In responding to the last group of gaps on further developing vulnerability research, a dynamic system analysis can accommodate the issues raised in this group as well as the first and second points above. A quantitative evaluation process using dynamic system analysis can simulate several adaptation scenarios through a modelling process. By comparing the output of vulnerability modelling (future vulnerability levels) for the different adaptation scenarios the most effective adaptation scenario to reduce future vulnerability can be determined.

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31 EVALUASI PROSES PENDAMPINGAN DALAM MENINGKATKAN KAPASITAS DAERAH MENGENAI GAS RUMAH KACA DAN UPAYA MITIGASI

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Abstrak – *Perpres 61 tahun 2011 mengamanatkan pemerintah daerah untuk berperan dalam pengurangan emisi dan risiko perubahan iklim. PSKBPI dan GIZ-PAKLIM telah melakukan pendampingan kepada Kabupaten Probolinggo selama 8 bulan. Pendampingan dilakukan dalam dua jenis tindakan yaitu lokakarya bersama dan pendampingan teknis berkala baik pada kelompok kecil SKPD maupun pada masing-masing SKPD. Berdasarkan hasil evaluasi dengan metode inferensi non parametrik melalui Uji Wilcoxon Signed Ranks, peserta mengalami peningkatan pemahaman pada 9 materi pokok GRK dan mitigasinya. Dengan 5 metode utama dan 6 catatan khusus dalam penyampaian materi, peserta memiliki penilaian baik dan sangat baik kepada fasilitator dalam menyampaikan materi.*

Kata Kunci: *Pendampingan, Mitigasi, Gas Rumah Kaca*

I. PENDAHULUAN

Pemanasan global mengakibatkan perubahan iklim dan kenaikan frekuensi maupun intensitas kejadian cuaca ekstrim. Hasil kajian IPCC, 2007 (dalam Kementerian Lingkungan Hidup, 2007) menunjukkan bahwa 11 dari 12 tahun terpanas sejak tahun 1850 terjadi dalam waktu kurun 12 tahun terakhir. Kenaikan temperatur total dari tahun 1850-1899 sampai dengan tahun 2001-2005 adalah 0,76°C. Muka air laut rata-rata global telah meningkat dengan laju rata-rata 1,8 mm per-tahun dalam rentang waktu antara tahun 1961 sampai 2003. Kenaikan total muka air laut yang berhasil dicatat pada abad ke-20 diperkirakan 0,17 m.

Pemanasan global yang menyebabkan perubahan iklim menimbulkan dampak kerugian ekonomi sosial yang cukup signifikan. Menurut World Disaster Report, 2001 (dalam Kementerian Lingkungan Hidup, 2007) menyebutkan kerugian ekonomi akibat bancana iklim di tingkat global yang terjadi sekarang dibanding dengan yang terjadi di tahun 1950an sudah meningkat 14 kali, yaitu mencapai 50-100 milyar USD per-tahun. Oleh karena itu diperlukan upaya penanganan terhadap dampak perubahan iklim melalui manajemen resiko iklim pada jangka panjang. Upaya ini memerlukan pendekatan lintas sektor, lintas wilayah, dan lintas kewenangan pada tingkat nasional, regional maupun lokal.

Komitmen Indonesia dalam menjaga iklim global sudah menjadi perhatian sejak tahun 1990an. Pada tingkat nasional, berbagai upaya yang dikembangkan dalam menghadapi dampak perubahan iklim ini adalah melalui formulasi kebijakan-kebijakan yang berkaitan dengan rencana aksi nasional mitigasi maupun adaptasi perubahan iklim. Peraturan Presiden No.61 Tahun 2011 mengenai Rencana Aksi Nasional (RAN) Penurunan Emisi Gas Rumah Kaca merupakan upaya pengembangan aksi mitigas perubahan iklim melalui penurunan emisi/peningkatan penyerapan Gas Rumah Kaca (GRK) dari berbagai sumber emisi. Kebijakan pengembangan RAN Penurunan Emisi GRK ini didasari pula oleh komitmen Pemerintah Indonesia dalam pertemuan G-20 di Pittsburg untuk menurunkan emisi gas rumah kaca sebesar 26% dengan usaha sendiri dan mencapai 41% jika mendapat bantuan internasional pada tahun 2020. Adanya target pengurangan emisi GRK nasional ini menjadi keharusan bagi daerah Provinsi untuk merumuskan aksi-aksi mitigasi perubahan iklim yang dituangkan dalam Rencana Aksi Daerah (RAD) penurunan GRK. Selanjutnya pada tingkat nasional, formulasi kebijakan dan strategi mengenai upaya adaptasi terhadap perubahan iklim tertuang dalam Rencana Aksi Nasional Adaptasi Perubahan Iklim (RAN-API). RAN-API ini memuat strategi pembangunan dan rencana-rencana aksi yang menjamin adanya ketahanan terhadap perubahan iklim. RAN-API ini dapat menjadi input dan pedoman bagi penyusunan Rencana Kerja Pemerintah Daerah (RKPD) dan Rencana Pembangunan Jangka Menengah Daerah (RPJMD), baik pada level nasional maupun daerah, untuk memastikan agar di masa mendatang rencana dan program pembangunan semakin responsif terhadap perubahan iklim. Oleh karena itu, komitmen nasional harus didukung pula oleh komitmen di daerah dalam mengupayakan aksi-

aksi mitigasi dan adaptasi terhadap perubahan iklim.

Kabupaten Probolinggo sebagai salah satu kabupaten yang memiliki peran strategis dalam pengembangan wilayah Jawa Timur mulai merasakan adanya gejala-gejala perubahan iklim, seperti kenaikan muka air laut, cuaca ekstrim, kenaikan suhu udara, maupun perubahan pola curah hujan dan sebagainya. Dampak akibat perubahan iklim ini adalah adanya permasalahan pada sektor air bersih (beberapa wilayah mengalami krisis air bersih), kekeringan, banjir, peningkatan wabah penyakit, dan sebagainya. Komitmen daerah diperlukan untuk mengurangi dampak dari perubahan iklim ini, serta komitmen dalam melakukan upaya-upaya pengendalian untuk mengurangi resiko akibat perubahan iklim yaitu melalui pengurangan emisi GRK atau peningkatan penyerapan GRK.

Komitmen dalam mengupayakan aksi mitigasi dan adaptasi di Kabupaten Probolinggo dapat dituangkan dalam rencana dan program-program pembangunan daerahnya. Pemerintah daerah sebagai aktor strategis dalam pengambilan kebijakan dan keputusan atas pembangunan di daerahnya perlu didukung dengan kapasitas dan kapabilitasnya dalam perumusan aksi mitigasi dan adaptasi terhadap perubahan iklim di daerah. Pada bulan Februari tahun 2014, melalui kegiatan PAKLIM (Program Advis Kebijakan Lingkungan dan Perubahan Iklim) yang merupakan kerjasama Indonesia dengan Institusi Jerman (GIZ- Gesellschaft für Internationale Zusammenarbeit), mengembangkan kegiatan pendampingan pada sejumlah SKPD (Satuan Kerja Perangkat Daerah) mengenai penyusunan rencana aksi mitigasi dan adaptasi terhadap perubahan iklim. Kegiatan pendampingan ini bekerjasama pula dengan LPPM-ITS yang berperan sebagai fasilitator. Upaya pendampingan kepada pemerintah daerah di Kabupaten Probolinggo dilakukan dengan serangkaian kegiatan lokakarya untuk menghasilkan dokumen rencana aksi mitigasi dan adaptasi terhadap perubahan iklim di daerah. Kegiatan pendampingan ini merupakan salah satu bentuk pengembangan kapasitas (*capacity building*).

Kegiatan pendampingan yang sudah terlaksana adalah berkaitan dengan upaya perumusan aksi mitigasi perubahan iklim. Kegiatan pendampingan ini dilakukan dalam serangkaian lokakarya dengan materi-materi terkait definisi mitigasi, metode kalkulkasi GRK (Gas Rumah Kaca), serta metode perumusan opsi/pilihan aksi mitigasi. Kegiatan ini diikuti oleh sejumlah SKPD yang termasuk kedalam tim POKJA Perubahan Iklim Kabupaten Probolinggo pada enam kali kegiatan pendampingan. Bentuk kegiatan pendampingan ini adalah berupa ceramah, diskusi, latihan/praktek, dan FGD (*Focus Group Discussion*). Oleh karena itu, pada kajian ini bertujuan untuk mengevaluasi sejauhmana kegiatan pendampingan yang dilakukan telah efektif meningkatkan kapasitas dan pemahaman SKPD terhadap upaya perumusan aksi mitigasi perubahan iklim di Kabupaten Probolinggo. Selain itu, kajian ini juga menunjukkan bagaimana pengaruh fungsi dan peran fasilitator dalam meningkatkan efektivitas pengembangan kapasitas pemerintah daerah Kabupaten Probolinggo.

II. DEFINISI PENGEMBANGAN KAPASITAS (*CAPACITY BUILDING*)

Pengembangan kapasitas (*capacity building atau capacity development*) adalah sebuah pendekatan yang pada masa sekarang ini secara luas digunakan dalam pembangunan masyarakat (*community development*). Istilah pengembangan kapasitas telah digunakan sejak tahun 1990an oleh negara-negara donor untuk memperbaiki kapasitas negara partner (negara yang mendapat bantuan). Untuk memahami konsep pengembangan kapasitas, terlebih dahulu perlu memahami pengertian tentang kapasitas.

Kapasitas (*capacity*) seperti halnya konsep keberlanjutan (sustainability) merupakan konsep yang bersifat elusif atau sukar dipahami dan multidimensi (Brown et al, 2001). Kapasitas dapat dideskripsikan sebagai kemampuan untuk melaksanakan sasaran yang sudah ditetapkan (Goodman, 1998 dalam Brown et al, 2001). Konsep pengembangan kapasitas (*capicity building*) berkaitan dengan sesuatu yang tidak mudah diukur (intangible). Kapasitas berkaitan dengan peningkatan kemampuan seseorang melalui partisipasi dalam kegiatan pelatihan atau mengikuti pendidikan (JICA, 2004). Dalam pengertian yang lebih luas, yang sekarang digunakan dalam pembangunan masyarakat, kapasitas tidak hanya berkaitan dengan keterampilan dan kemampuan individu, tetapi juga dengan kemampuan organisasi untuk mencapai misinya secara efektif dan kemampuan mempertahankan kelangsungan hidupnya dalam jangka panjang (UNDP, 2006). Dengan kata lain, kapasitas komunitas merupakan kemampuan yang dimiliki oleh kelompok atau lembaga untuk mencapai suatu misi.

Untuk mencapai suatu misi dari suatu komunitas, dalam hal ini adalah lembaga atau organisasi diperlukan suatu upaya pengembangan kapasitas. Menurut Uni Eropa, pengembangan kapasitas adalah proses yang dialami oleh individu, kelompok dan organisasi untuk memperbaiki kemampuan dalam melaksanakan fungsi dan mencapai hasil yang diinginkan (Morgan, 2004). Dari pengertian ini, terdapat penekanan pada dua hal penting: 1) pengembangan kapasitas sebagian besar berupa proses pertumbuhan dan pengembangan internal, dan 2) upaya-upaya pengembangan kapasitas haruslah berorientasi pada hasil. Secara umum, terminologi pengembangan kapasitas adalah aktivitas atau proses yang meningkatkan kemampuan seseorang atau entitas untuk melaksanakan sasaran-sasaran yang sudah

ditetapkan (Brown et al, 2001). Definisi terminologi pengembangan kapasitas sangat bervariasi dari definisi yang sangat umum hingga spesifik, bergantung pada konteks apa serta level mana konsep ini digunakan.

United Nation Development Program (UNDP) mendefinisikan pengembangan kapasitas sebagai suatu proses yang dialami oleh individu, kelompok, organisasi, lembaga dan masyarakat untuk meningkatkan kemampuan agar dapat: 1) melaksanakan fungsi-fungsi esensial, memecahkan masalah, menetapkan dan mencapai tujuan, serta 2) mengerti dan menangani kebutuhan pengembangan diri dalam suatu lingkungan yang lebih luas secara berkelanjutan (CIDA, 2000).

Pada kajia ini, peningkatan kapasitas daerah dikaitkan dengan terminologi pengembangan kapasitas (*capacity building*) yang menekankan pada aktivitas atau proses yang meningkatkan kemampuan individu atau entitas SKPD untuk melaksanakan upaya mitigasi perubahan iklim di Kabupaten Probolinggo. Orientasi hasil yang ingin dicapai dari proses ini adalah peningkatan pemahaman GRK dan upaya mitigasi.

III. METODE ANALISIS

Metode yang digunakan pada kajian ini adalah metode inferensi non parametrik melalui Uji Wilcoxon Signed Ranks. Metode ini bertujuan untuk melakukan pengujian terhadap efektivitas kegiatan pendampingan dalam perumusan aksi mitigasi perubahan iklim di Kabupaten Probolinggo. Efektivitas ini dilihat dari ada tidaknya perubahan pemahaman mengenai mitigasi perubahan iklim pada kondisi sebelum dan sesudah adanya kegiatan pendampingan. Penggunaan metode inferensi non parametrik ini didasarkan pada pengambilan kesimpulan populasi atas jumlah sampel yang tidak terlalu banyak serta tidak adanya asumsi normalitas pada pengujian yang dilakukan. Jumlah sampel yang digunakan pada kajian ini sebanyak 14 responden yang berasal dari perwakilan SKPD yang termasuk kedalam tim POKJA perubahan iklim Kabupaten Probolinggo. Sejumlah responden ini mengikuti keseluruhan kegiatan pendampingan mengenai materi perumusan aksi mitigasi. Oleh karena itu, semua responden memberikan penilaian terhadap dirinya mengenai pemahaman materi-materi mitigasi perubahan iklim pada kondisi sebelum dan sesudah mengikuti pendampingan. Penilaian terhadap tingkat pemahaman materi diukur dengan skala pengukuran ordinal (pemeringkatan) dengan nilai skala 1 artinya sangat tidak paham; skala 2 artinya tidak paham; skala 3 artinya sedang; skala 4 artinya paham; skala 5 artinya sangat paham. Melalui metode ini dilakukan pengujian hipotesa yang terdiri dari hipotesa awal (H0) dan hipotesa alternatif (H1) sebagai berikut:

H0 : pemahaman mengenai mitigasi perubahan iklim pada kondisi sebelum dan sesudah adanya pendampingan adalah sama, artinya kegiatan pendampingan tidak efektif mempengaruhi tingkat pemahaman SKPD

H1 : pemahaman mengenai perubahan iklim mitigasi pada kondisi sebelum dan sesudah adanya pendampingan adalah berbeda, artinya kegiatan pendampingan efektif mempengaruhi tingkat pemahaman SKPD

Kesimpulan atas pengujian hipotesa tersebut menggunakan tingkat kepercayaan 95% atau alpha 5%. Hipotesa awal (H0) ditolak jika nilai probabilitas < 0,05 dan sebaliknya H0 diterima jika nilai probabilitas > 0,05.

Pada kajian ini digunakan pula metode deskriptif untuk mengevaluasi bagaimana peran fasilitator dalam kegiatan pendampingan, serta persepsi penerima manfaat (dalam hal ini adalah SKPD) terhadap cara penyampaian dan penguasaan materi pendampingan. Hasil evaluasi ini akan menunjukkan sejauhmana efektivitas kegiatan pendampingan dipengaruhi oleh fungsi dan peran tim fasilitator.

IV. HASIL DAN PEMBAHASAN

Kegiatan pendampingan dilakukan pada serangkaian lokakarya yang bertujuan untuk meningkatkan pemahaman dan kapasitas pemerintah daerah Kabupaten Probolinggo dalam merumuskan aksi mitigasi perubahan iklim. Materi-materi yang disampaikan pada masing-masing lokakarya tersebut antara lain:

1. Definisi Mitigasi Perubahan Iklim
2. Perbedaan konsep Mitigasi dengan konsep Adaptasi dalam perubahan iklim
3. Definisi Gas Rumah Kaca (GRK)
4. Efek Gas Rumah Kaca (GRK)
5. Jenis-jenis aktivitas yang berperan sebagai sumber pengemisi Gas Rumah Kaca
6. Jenis-jenis data yang diperlukan dalam perhitungan emisi Gas Rumah Kaca
7. Metode perhitungan emisi Gas Rumah Kaca (Kalkulator GRK)
8. Metode proyeksi emisi Gas Rumah Kaca
9. Metode root cause diagram untuk menentukan opsi/aksi mitigasi

Kegiatan pendampingan perumusan aksi mitigasi ini dilakukan dalam enam kali lokakarya. Pada setiap lokakarya, metode penyampaiannya dapat dikategorikan kedalam 5 tipe utama penyampaian materi, yaitu;

1. Penyampaian materi inti melalui metode kuliah dengan susunan peserta melingkar selama maksimum 20-30 menit. Penyampaian materi kuliah ini dapat dilihat pada Gambar 1

Gambar 1 Kondisi Pendampingan Pada Sesi Materi Inti

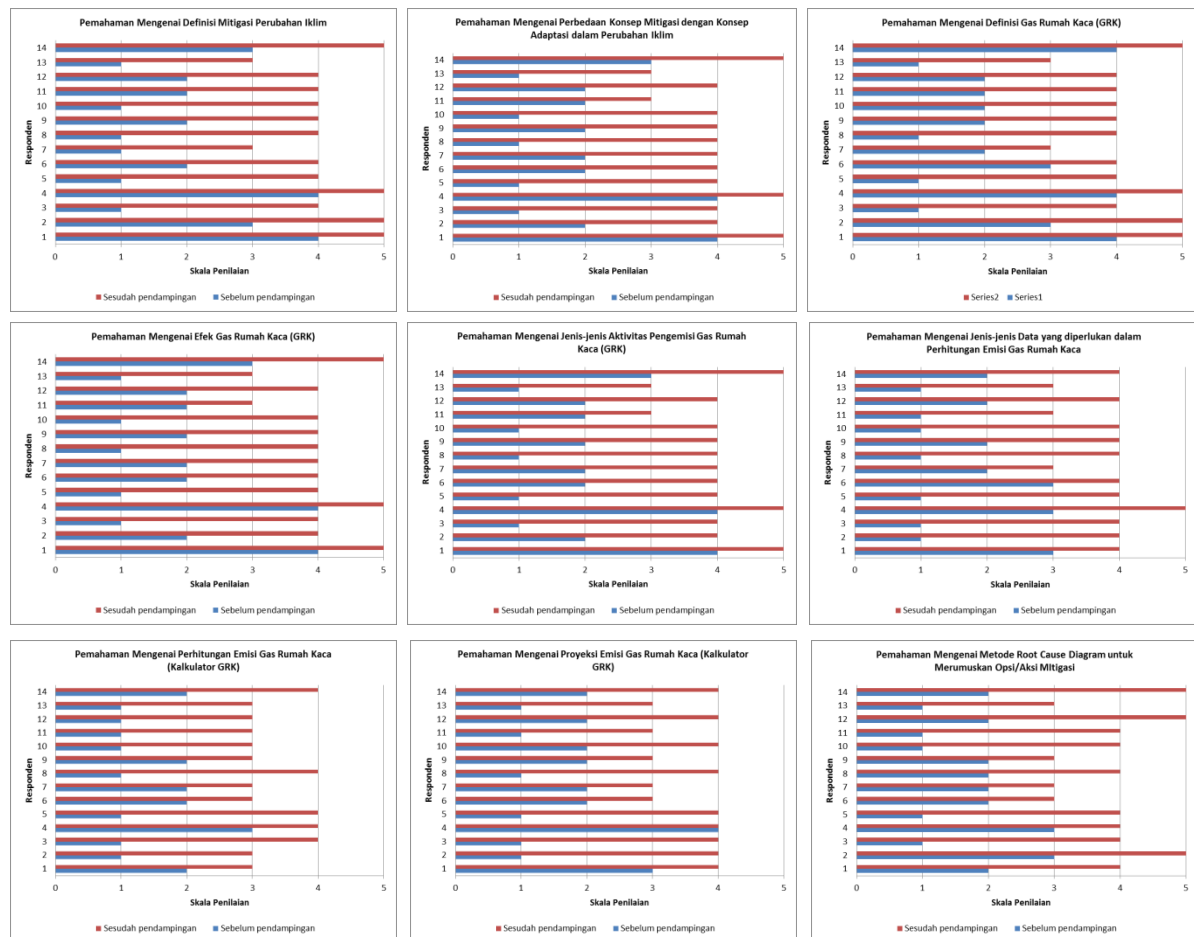
2. Diskusi materi inti dengan pertanyaan baik dari peserta maupun fasilitator. Berbagai pertanyaan dari peserta ini sangat penting untuk memastikan apakah materi yang disampaikan sudah diterima dengan baik.
3. Penyampaian ulasan materi pada setiap pergantian materi inti atau diskusi kelompok. Pada setiap awal sesi, fasilitator selalu mengulas materi yang sudah disampaikan. Pengulangan materi ini bertujuan untuk mengingatkan peserta dan sekaligus menghubungkan pemahaman peserta dari materi satu dengan materi lainnya. Pengulasan ini bisa dilakukan melalui paparan slides maupun diskusi atas pertanyaan yang disampaikan oleh fasilitator.
4. Diskusi kelompok dengan metode pinboard. Metode ini berupaya mengaktifkan gerak tubuh peserta untuk mengurangi kejenuhan peserta dengan cara meminta peserta menuliskan ide dalam kertas yang ditempelkan di board dengan sebuah pin. Dengan metode ini, peserta diminta menempelkan kertas berisi idenya di papan yang sudah disediakan untuk didiskusikan kembali baik di level kelompok maupun pleno (Gambar 2).

Gambar 2 Situasi Peserta menggunakan Pin Board dalam Diskusi Kelompok

5. Diskusi pleno dengan presentasi hasil dari masing-masing kelompok kepada seluruh peserta. Setelah menyelesaikan diskusi kelompok, peserta diminta untuk mempresentasikan hasilnya kepada kelompok lain. Presentasi ini dilanjutkan dengan tanya jawab untuk mendapatkan kesepakatan dari pleno. Gambar 3 menunjukkan peserta mempresentasikan hasil diskusi kelompok dengan metode pinboard.

Gambar 3 Situasi Peserta menjelaskan Hasil Diskusi Kelompoknya menggunakan Pin Board

A. *Evaluasi Kegiatan Pendampingan terhadap Pemahaman Materi*

Berdasarkan hasil kusioner yang sudah disebarkan, beberapa responden melakukan penilaian terhadap dirinya mengenai tingkat pemahamannya pada kondisi sebelum dan sesudah adanya pendampingan. Pada Gambar 4 berikut menunjukkan deskripsi tingkat pemahaman responden pada kondisi sebelum dan sesudah adanya pendampingan

Gambar 4 Diagram Perbandingan Tingkat Pemahaman Materi Aksi Mitigasi pada Kondisi Sebelum dan Sesudah Adanya Pendampingan (Sumber: hasil analisis, 2014)

Berdasarkan deskripsi dari diagram diatas dapat dilihat bahwa adanya perubahan tingkat pemahaman SKPD terhadap materi aksi mitigasi pada kondisi sebelum dan sesudah adanya kegiatan pendampingan. Penilaian sesudah adanya pendampingan yang rata-rata lebih tinggi dibandingkan kondisi sebelumnya menunjukkan adanya peningkatan pemahaman. Untuk menguji secara siginifikan apakah kegiatan pendampingan efektif atau tidak, maka dilakukan pengujian hipotesa melalui Uji Wilcoxon Signed Ranks yang dihasilkan seperti pada tabel 1 berikut.

Tabel 1 Pengujian Hipotesa Sebelum dan Sesudah Adanya Kegiatan Pendampingan berdasarkan Materi Perumusan Aksi Mitigasi melalui Uji Wilcoxon Signed Ranks

No	Materi Kegiatan Pendampingan Perumusan Aksi Mitigasi	Wilcoxon Signed Ranks Tests (p-value) *)	Kesimpulan Pengujian Hipotesa
1	Definisi Mitigasi Perubahan Iklim	0,01	H0 ditolak
2	Perbedaan konsep Mitigasi dengan konsep Adaptasi dalam perubahan iklim	0,01	H0 ditolak
3	Definisi Gas Rumah Kaca (GRK)	0,01	H0 ditolak
4	Efek Gas Rumah Kaca (GRK)	0,01	H0 ditolak
5	Jenis-jenis aktivitas yang berperan sebagai sumber pengemisi Gas Rumah Kaca	0,02	H0 ditolak
6	Jenis-jenis data yang diperlukan dalam	0,01	H0 ditolak

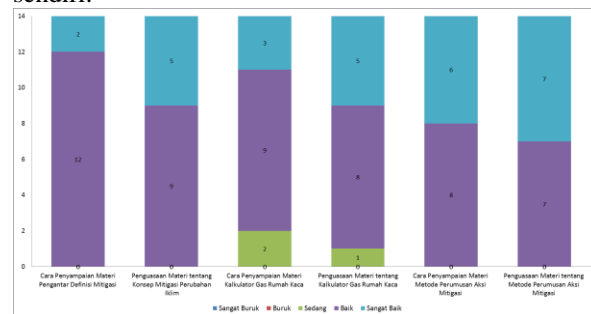
	perhitungan emisi Gas Rumah Kaca		
7	Metode perhitungan emisi Gas Rumah Kaca (Kalkulator GRK)	0,01	H0 ditolak
8	Metode proyeksi emisi Gas Rumah Kaca berdasarkan tahun dasar dan tahun perkiraan	0,01	H0 ditolak
9	Metode *root cause diagram* untuk merumuskan opsi/aksi mitigasi	0,01	H0 ditolak

*Keterangan *) merupakan uji dua sisi yang dihasilkan melalui pengolahan data dengan SPSS 17.*

Berdasarkan pengujian hipotesa melalui Uji Wilcoxon Signed Ranks disimpulkan bahwa pada tingkat kepercayaan 95%, kegiatan pendampingan yang dilakukan efektif meningkatkan pemahaman SKPD terhadap materi perumusan aksi mitigasi perubahan iklim. Hal ini dapat dilihat semua nilai probabilitas kurang dari 0,05. Pengujian ini menunjukkan bahwa adanya perubahan yang signifikan terhadap pemahaman SKPD pada kondisi sebelum dan sesudah adanya kegiatan pendampingan. Peningkatan pemahaman ini akan meningkatkan kapasitas pemerintah daerah Kabupaten Probolinggo dalam perumusan opsi/aksi mitigasi yang lebih konkrit. Dengan kata lain, proses pendampingan ini telah berhasil meningkatkan pemahaman peserta terhadap perubahan iklim dan mitigasinya.

B. *Evaluasi Kegiatan Pendampingan terhadap cara penyampaian dan Penguasaan Materi oleh Tim Fasilitator*

Dengan lima metode penyampaian di atas, penilaian responden terhadap cara penyampaian ini terlihat sudah cukup positif. Penilaian responden didominasi oleh penilaian dengan kategori baik dan sangat baik. Komposisi antara penilaian baik dan sangat baik terlihat berubah-ubah masih dapat dikatakan wajar sebagai bagian dari dinamika didalam proses penyampaian itu sendiri pada masing-masing materi.

Berdasarkan Gambar 5 dapat dilihat bagaimana persepsi penilaian penerima manfaat (SKPD) terhadap cara penyampaian dan penguasaan materi oleh tim fasilitator pada saat pendampingan. Secara umum, cara penyampaian dikategorikan baik hingga sangat baik. Namun, pada bagian materi kalkulator Gas Rumah Kaca (GRK) terdapat penilaian sedang oleh penerima manfaat. Kalkulator GRK merupakan materi yang tersulit untuk disampaikan mengingat adanya perhitungan khusus dan pemahaman yang spesifik mengenai bahan atau materi penghasil emisi. Beberapa anggota tim POKJA tidak memiliki background keilmuan ataupun pengalaman praktis di bidang ini. Topik yang mendapatkan penilaian sangat baik terbanyak berada di perumusan aksi mitigasi. Hal ini cukup dapat dimaklumi karena anggota tim POKJA memiliki kedekatan materi tersebut dengan kegiatan yang ditangani sehari-hari yaitu membuat program kerja daerah. Oleh karenanya, pemahaman dan background sehari-hari peserta pendampingan ini sangatlah menentukan pemahaman dari peserta itu sendiri.

Gambar 5 Diagram Penilaian SKPD terhadap Cara Penyampaian dan Penguasaan Materi oleh Tim Fasilitator(Sumber: hasil analisis, 2014)

V. DISKUSI

Dari kelima metode penyampaian pendampingan GRK ke Kabupaten Probolinggo, ada beberapa catatan perlu dilakukan untuk meningkatkan efektivitas pendampingan. Catatan tersebut sangatlah berguna dalam mengadopsi teknik pendampingan ini pada kasus-kasus lainnya. Catatan tersebut adalah:

1. Fasilitator dapat juga mendorong peserta dengan memberikan pertanyaan/penjelasan ringan terkait dengan materi. Pertanyaan atau penjelasan itu dapat dilakukan melalui proses analogi kesehari-harian. Gambar 6 mengilustrasikan proses penyampaian analogi.

Gambar 6 Menganalogikan Kejadian Perubahan Iklim dengan Kondisi Terperangkap di dalam Mobil Tanpa Bisa Menyalakan AC di Siang Hari yang Terik

2. Pendampingan individual kepada peserta berkharakteristik 'khusus', misalnya; sangat aktif, sangat tidak aktif, sangat aktif tapi kurang relevan, dsb. Pendampingan ini juga tetap sangat berguna untuk menjaga kondisi forum secara keseluruhan. Pendampingan individual ini dapat dilakukan dengan menjelaskan secara individual, mengarahkan kepada forum, mengunjungi setiap kelompok secara berkala ataupun mempersilahkan peserta yang kurang mendapat ruang untuk berbicara. Gambar 7 mengilustrasikan upaya-upaya tersebut.

Gambar 7 Upaya Pendampingan Khusus Pada Individu ataupun Kelompok 'Berkharateristik Khusus'

3. Untuk menjaga suasana cair, fasilitator dapat juga memberikan pertanyaan ringan, '*candid camera'* atau media '*ice breaker*' lainnya kepada peserta. *Ice breaker* ini dapat disampaikan pada saat awal materi, sedang berlangsung maupun sesudah acara berlangsung. Suasana cair ini dapat sebagaimana pada Gambar 8.

Gambar 8 Berbagai Media dapat dijadikan sebagai Ice Breaker Kegiatan Pendampingan

4. Kunjungan kepada masing-masing SKPD dalam memperkaya atau mengonfirmasikan hasil kesepakatan forum. Berbagai diskusi dari yang sudah dilakukan bersama seringkali memerlukan data yang lebih detail terkait hasil kesepakatan. Kunjungan kepada SKPD ini sangatlah berguna dalam mendalami hasil diskusi tersebut. Kunjungan ini dapat juga meningkatkan relasi yang terjadi antara fasilitator dengan SKPD selaku peserta pendampingan.
5. Selalu berkala menghubungi SKPD terkait jika ada kegiatan bersama maupun pengumpulan data. Dengan kesibukan masing-masing SKPD menangani tupoksinya, upaya mengingatkan perlu dilaksanakan secara berkala. Proses pengingat ini dilakukan dengan beragam cara baik online maupun offline.
6. Ikut serta dalam kegiatan daerah terkait GRK. Untuk mempererat hubungan antara fasilitator dan peserta pendampingan, pihak PSKBPI ITS telah menjadi salah satu peserta pameran yang diselanggarakan daerah maupun Paklim-GIZ. Keikutsertaan ini tidak saja akan berguna dalam memberikan pemahaman GRK pada masyarakat luas tetapi juga dapat mempererat hubungan fasilitator dengan peserta pendampingan. Fasilitator juga dapat memahami antusiasme atau pun kemampuan peserta dalam menjelaskan GRK kepada khalayak masyarakat luas. Gambar 9 adalah stand yang diikuti oleh PSKBPI ITS dalam pameran lingkungan di Kabupaten Probolinggo.

Gambar 9 Keikutsertaan PSKBPI ITS dalam Pameran Lingkungan di Daerah

VI. KESIMPULAN

Dari proses pendampingan yang dilakukan, POKJA GRK di Kabupaten Probolinggo telah melakukan upaya peningkatan pemahaman tentang GRK dan mitigasinya melalui kerjasama dengan PAKLIM GIZ dan PSKBPI ITS. Pihak pemerintah daerah menyakini bahwa efek GRK sudah terjadi di Kabupaten Probolinggo. Melalui berbagai proses pendampingan selama 7 bulan, pemahaman yim Pokja GRK telah mengalami peningkatan terutama pada 9 materi pokok GRK. Proses pendampingan tersebut pun telah dinilai oleh Pokja sebagai proses

pendampingan bernilai baik dan sangat baik. Hal ini tentunya dilakukan dengan mengkombinasi kelima metode utama dengan 6 catatan khusus dalam meningkatkan proses pendampingan.

UCAPAN TERIMA KASIH

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Deteksi Iklim Ekstrim dengan Pendekatan Copula sebagai *Early Warning System* pada Produksi Padi di Lamongan Jawa Timur

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Abstrak – *Lamongan adalah salah satu kabupaten di Jawa Timur yang mempunyai produktivitas terbesar di Jawa Timur, yaitu sebesar 63,60 Kw/Ha (BPS, 2013) dan tercatat menjadi penghasil padi terbesar kedua di Jawa Timur. Produksi padi Lamongan tahun 2013 sebesar 967.497 ton Gabah Kering Giling (GKG). Produksi padi Lamongan meningkat dari tahun sebelumnya sekitar 55.643 ton GKG atau sekitar 6,1 persen. Meskipun Lamongan menjadi salah satu penghasil padi terbanyak di Jawa Timur, Lamongan masih rawan terjadi bencana banjir dan kekeringan yang memberikan dampak negatif terhadap produksi padi. Hal ini menunjukkan bahwa iklim, khususnya curah hujan, sangat mempengaruhi produksi padi karena curah hujan turut menentukan masa tanam padi. Curah hujan memiliki keragaman dan fluktuatif yang tinggi. Keragaman curah hujan dipengaruhi oleh fenomena di Lautan Pasifik, yaitu ENSO (El Nino-Southern Oscillation). ENSO mengukur perubahan yang terjadi pada suhu permukaan laut di timur Pasifik. Pada penelitian ini, akan digunakan pendekatan Copula. Pendekatan Copula memberikan hasil yang tepat untuk data pengamatan ekstrim dan untuk kondisi dengan asumsi-asumsi kenormalan yang terlanggar. Oleh karena itu dilakukan identifikasi hubungan antara curah hujan dan indikator ENSO di Kabuoaten Lamongan. Metode yang digunakan adalah dengan pendekatan Copula, karena pola hubungan curah hujan dan ENSO di Kabupaten Lamongan tidak mengikuti distribusi normal. Selain itu, analisis korelasi klasik tidak dapat mengidentifikasi pola hubungan keduanya. Hasil penelitian menunjukkan struktur dependensi antara curah hujan dan Anomali SST Nino 3 di Kabupaten Lamongan sebagian besar mengikuti Copula Frank. Sementara itu, struktur dependensi antara curah hujan dan Anomali SST Nino 4 serta SST Nino 3.4 mengikuti Copula Clayton, sedangkan dengan Anomali SST Nino 1+2 tidak mengikuti Copula apapun. Kesimpulan lain diperoleh bahwa kejadian ENSO pada bulan tertentu berpengaruh terhadap curah hujan di Kabupaten Lamongan setelah satu bulan berikutnya.*

Kata kunci: *Produksi Padi, Copula, ENSO, Iklim Ekstrim*

I. PENDAHULUAN

Jawa Timur salah satu provinsi yang memberikan kontribusi besar dalam produksi padi nasional dengan produktivitas sebesar 59,15 Kw/Ha. Lamongan adalah salah satu kabupaten di Jawa Timur yang mempunyai produktivitas terbesar di Jawa Timur, yaitu sebesar 63,60 Kw/Ha [1] dan tercatat menjadi penghasil padi terbesar kedua di Jawa Timur. Produksi padi Lamongan tahun 2013 sebesar 967.497 ton Gabah Kering Giling (GKG). Produksi padi Lamongan meningkat dari tahun sebelumnya sekitar 55.643 ton GKG atau sekitar 6,1 persen.

Meskipun Lamongan menjadi salah satu penghasil padi terbanyak di Jawa Timur, Lamongan masih rawan terjadi bencana banjir dan kekeringan yang memberikan dampak negatif terhadap produksi padi dan menimbulkan kerugian bagi petani pada khususnya.Curah hujan yang tinggi di akhir 2013 dan awal 2014 menyebabkan petani cenderung tanam padi pada musim tersebut, sehingga hal tersebut menimbulkan adanya pergeseran tanam palawija ke padi. Hal ini menjadi salah satu penyebab luas panen tahun 2013 meningkat [2]. Selain itu, sejak bulan Januari hingga Juli 2013, terdapat 1.505,4 hektar tanaman padi di Lamongan diserang hama wereng dengan sebaran, meliputi Kecamatan Turi, Pucuk, Lamongan, Kali Tengah, Babat, Sekaran, Maduran, dan Sukodadi. Dari luas area yang terserang hama wereng, 78 hektar dinyatakan puso atau gagal panen. Oleh karena adanya upaya penggunaan pembasmi hama yang efektif, dapat membuat produksi padi Lamongan tetap terjaga bahkan meningkat.

Peningkatan produktivitas padi dengan cara modernisasi juga dapat meningkatkan produksi padi Lamongan.

Pada tahun 2013, Lamongan mengalami gagal panen sekitar 11 hektar. Di seluruh wilayah Jawa Timur, ada sekitar 3.874 hektar lahan padi yang mengalami kekeringan selama tahun 2014. Dari jumlah lahan padi yang kekeringan tersebut, 601,5 hektar yang mengalami gagal panen dan Lamongan mengalami gagal panen seluas 64 hektar [2]. Lahan padi yang paling luas terkena banjir (terendam air) berada di Bojonegoro, yakni 5.048 hektar, di Tuban seluas 700 hektar, dan di Lamongan seluas 348 hektar. Dampak banjir ini disebut ancaman gagal panen.

Hal ini menunjukkan bahwa iklim, khususnya curah hujan, sangat mempengaruhi produksi padi karena curah hujan turut menentukan masa tanam padi. Curah hujan memiliki keragaman dan fluktuatif yang tinggi di Indonesia. Setiap daerah di Indonesia memiliki karakteristik curah hujan yang berbeda-beda. Keragaman curah hujan di Indonesia dipengaruhi oleh fenomena di Lautan Pasifik, yaitu ENSO (*El Nino-Southern Oscillation*). ENSO mengukur perubahan yang terjadi pada suhu permukaan laut di timur Pasifik [3]. ENSO memiliki dua fase yang berbeda, yaitu El Nino yang umumnya membawa dampak berupa berkurangnya curah hujan bahkan kekeringan, sedangkan La Nina membawa dampak berupa meningkatnya curah hujan yang dapat menyebabkan banjir. Penelitian mengenai keterkaitan curah hujan dan ENSO yang dilakukan oleh [4] menyimpulkan adanya hubungan antara ENSO dan variasi curah hujan di Indonesia.

Pada penelitian ini, akan digunakan metode statistika yang dapat menggambarkan hubungan antar variabel yang tidak terlalu ketat terhadap asumsi distribusi, serta dapat menunjukkan hubungan dependensi pada titik-titik ekstrim dengan jelas, yaitu dengan Copula. Metode ini mempunyai kemampuan untuk mendeskripsikan struktur dependensi antar variabel dengan marginal yang berbeda dan memodelkan dependensi *tail*-nya. Copula adalah suatu fungsi dari dua hubungan distribusi yang masing-masing mempunyai fungsi marginal distribusi [5]. Beberapa penelitian mengenai Copula telah dilakukan, antara lain penelitian oleh [6] mengenai penggunaan Copula pada kasus kesehatan. [7] menerapkan Copula untuk memodelkan asuransi. [8] menerapkan Copula pada bidang klimatologi. Hasil penelitian menunjukkan pendekatan dengan Copula memberikan hasil yang tepat untuk data pengamatan ekstrim dan untuk kondisi dengan asumsi-asumsi kenormalan yang terlanggar. Begitu juga dengan penelitian ini menggunakan pendekatan Copula untuk mengetahui pola hubungan curah hujan dan indikator ENSO. Penelitian ini dilakukan di Kabupaten Lamongan, Jawa Timur yang merupakan salah satu daerah sentra produksi padi Jawa Timur sebagai upaya *Early Warning System* di Lamongan, Jawa Timur.

II. TINJAUAN PUSTAKA

A. *Konsep Dasar Copula*

Apabila terdapat vektor random $\left(X_1, X_2, ..., X_m\right)$ memiliki fungsi distribusi kumulatif marginal $F_{X1}, F_{X1}, ..., F_{Xm}$ dengan domain $\mathbf{R}$ yang tida[‘k turun, yaitu $F_{X_i}\left(-\infty\right)=0$ dan $F_{X_i}\left(\infty\right)=1$, maka distribusi bersamanya seperti persamaan (1).

$$F_{(X_1,X_2,...,X_m)}\left(x_1,x_2,...,x_m\right)= C_{(X_1,X_2,...,X_m)}\left(F_{X_1}\left(x_1\right),F_{X_2}\left(x_2\right),...,F_{X_m}\left(x_m\right)\right) \quad (1)$$

$C_{(X_1,X_2,...,X_m)}$ adalah Copula dengan

$C_x:\left[0,1\right]^m \rightarrow \left[0,1\right]$. Jika fungsi distribusimarginal $F_{X_i}\left(X_i\right)$ kontinu, $C_{(X_1,X_2,...,X_m)}$ adalah unik [8] dan dapat ditunjukkan pada persamaan (2).

$$C_{(X_1,X_2,...,X_m)}\left(u_1,u_2,...,u_m\right)= \int_0^{u_1}...\int_0^{u_2}\int_0^{u_m} c_{(X_1,X_2,...,X_m)}\left(u_1,u_2,...,u_m\right)du_1du_2...du_m \quad (2)$$

C adalah Copula dan c adalah persamaan densitas Copula. Pada kasus distribusi kontinu, struktur dependensi multivariat dan distribusi marginal dapat dipisahkan dan Copula dapat dianggap *independent margin*.

B. *Tranformasi Copula ke Domain Uniform[0,1]*

Distribusi marginal dari masing-masing variabel random X_i ditunjukkan pada persamaan (3) berikut.

$$F_{X_i}\left(x_i\right)=\frac{1}{n+1}\sum_{j=1}^{n}\mathbf{1}\left(X_i^{(j)}\le x\right);x_i\in R \quad (3)$$

Transformasi ke domain Uniform[0,1] dengan pembuatan *scatterplot* [0,1], membuat rank plot X_i.

$$\left(\left(\frac{R_1^{(j)}}{n+1}\right),\left(\frac{R_2^{(j)}}{n+1}\right),...,\left(\frac{R_m^{(j)}}{n+1}\right)\right),1\le j\le n \quad (4)$$

dengan $R_1^{(j)},R_2^{(j)},...,R_m^{(j)}$ adalah rank dari $X_1,X_2,...,X_m$ yang sebelumnya sudah diubah menjadi bentuk matriks. Sesuai transformasi persamaan (4) persamaan Copula diberikan pada persamaan (5) berikut [9].

$$C(u_1,...,u_m) = \frac{1}{n}\sum_{j=1}^{n}\mathbf{1}\left(\frac{R_1^{(j)}}{n+1} \le u_1,..., \frac{R_n^{(j)}}{n+1} \le u_m\right) \quad (5)$$

$$u_1,...,u_m \in (0,1)$$

dengan $\mathbf{1}(.)$ pada persamaan (3) dan (5) merupakan fungsi indikator jika masing-masing $X^{(j)} \le x$ dan $\frac{R_i^{(j)}}{n+1} \le u_i, i = 1,2,...,m$ [10].

C. *Keluarga* Copula

Copula Gaussian atau Copula Normal merupakan salah satu keluarga Copula Elips. Copula Archimedean terdiri atas Copula Clayton, Gumbel, dan Frank. Copula Gaussian diperoleh dari transformasi variabel random ke distribusi normal standar. Fungsi Copula Gaussian diberikan pada persamaan (6) berikut.

$$C_{(X_1,X_2,...,X_m)}(u_1,u_2,...,u_m) = F_{N(0,\Sigma)}\left(F_{N(0,1)}^{-1}(u_1), F_{N(0,1)}^{-1}(u_2),...,F_{N(0,1)}^{-1}(u_m)\right) \quad (6)$$

Jika Copula Normal digunakan pada distribusi normal multivariat, maka diasumsikan hubungannya linear [11].

Copula Clayton memiliki *tail* dependensi bagian bawah, Copula Frank tidak memiliki *tail* dependensi, sedangkan Copula Gumbel memiliki *tail* dependensi bagian atas [11].

Tabel 2. *Keluarga Copula Archimedean*

Copula	**Generator** $\phi(u)$	**Copula Bivariat** $C(u_1,u_2)$
Clayton	$\frac{u^{-\theta}-1}{\theta}, \theta \in (0,\infty)$	$\left(u_1^{-\theta}+u_2^{-\theta}-1\right)^{-\frac{1}{\theta}}$
Gumbel	$(-\log(u))^{\theta}, \theta \in [1,\infty)$	$\exp\left\{-\left[(-\log(u_1))^{\theta}+(-\log(u_2))^{\theta}\right]^{\frac{1}{\theta}}\right\}$
Frank	$\log\left(\frac{e^{\theta u}-1}{e^{\theta}-1}\right), \theta \in R\setminus\{0\}$	$\frac{1}{\theta}\log\left(1+\frac{(e^{\theta u_1}-1)(e^{\theta u_2}-1)}{(e^{\theta}-1)}\right)$

D.Estimasi Parameter Copula dengan MLE

Fungsi densitas *f* ditulis dalam bentuk Copula pada persamaan (7).

$$f(x_1,...,x_m) = c\{F_{X_1}(x_1),...,F_{X_m}(x_m)\} f_{X_1}(x_1)\times...\times f_{X_m}(x_m); x \in R \quad (7)$$

dengan MLE, fungsi likelihood L dan log likelihood dituliskan pada persamaan (8).

$$L = \prod_{j=1}^{n} f\left(x_1^{(j)},...,x_m^{(j)}\right)$$

$$\ln L = \sum_{j=1}^{n}\ln c\left\{F_{X_1}\left(x_1^{(j)}\right),...,F_{X_m}\left(x_m^{(j)}\right)\right\} + \sum_{i=1}^{m}\sum_{j=1}^{n}\ln\left(f_{X_i}\left(x_i^{(j)}\right)\right) \quad (8)$$

Estimasi parameter Copula Archimedean dengan pendekatan Tau Kendall [12] diberikan pada persamaan (9) adalah estimasi θ dari θ.

$$\hat{\tau}_C = 1 + 4\int_0^1 \frac{\phi(u)}{\phi'(u)}du \quad (9)$$

Tabel 3. Estimasi Parameter Copula Archimedean

Copula	**Estimasi** θ
Clayton	$\hat{\tau} = \frac{\theta_C}{\theta_C+2}$ maka $\hat{\theta}_C = \frac{2\tau}{1-\tau}$
Gumbel	$\hat{\tau} = 1-\frac{1}{\theta_G}$ maka $\hat{\theta}_G = \frac{1}{1-\tau}$
Frank	$\hat{\tau} = 1-4(1-D_1(\theta_F))/\theta_F$ dimana $D_k(x) =$ Fungsi Debye $D_k(x) = \frac{k}{x^k}\int_0^x \frac{u^k}{e^u-1}du$

E. Pengujian Estimasi Parameter Copula

Pengujian estimasi parameter Copula untuk mengetahui parameter yang signifikan. [13] mendefinisikan di bawah hipotesis nol variabel random mengikuti beberapa model Copula dengan distribusi menjadi $\sqrt{n}Z_n \to N(0,1)$ adalah distribusi normal standar. Hipotesis dapat didefinisikan sebagai berikut.

$H_0 : \theta = \theta_0$

$H_1 : \theta \ne \theta_0$

Statistik uji:

$$z = \frac{\hat{\theta}-\theta_0}{SE(\hat{\theta})} \quad (10)$$

Daerah penolakan: Tolak H_0 jika $|z| > z_{\alpha/2}$ atau *p-value* < α.

III. METODOLOGI PENELITIAN

A. Sumber Data

Data yang digunakan adalah data sekunder dari Badan Meteorologi, Klimatologi dan Geofisika (BMKG) dan NOAA *National Weather Service* yang dapat diakses melalui http://www.cpc.ncep.noaa.gov/.

B. Variabel Penelitian

Variabel yang digunakan dalam penelitian ini ditunjukkan pada Tabel 3, adalah sebagai berikut.

1. Data bulanan curah hujan dari BMKG periode tahun 1982-2013 di lima kabupaten Jawa Timur.
2. Data bulanan ENSO (*El Nino-Southern Oscillation*) anomali *Sea Surface Temperature* (SST) Nino 1+2, SST Nino 3, SST Nino 4, dan SST Nino 3.4 dari NOAA periode tahun 1982-2013.

Tabel 4. Variabel Penelitian

No.	Nama Variabel	
1	CH.Lam	= Curah Hujan di Lamongan
2	ANOM 1+2	= Anomali SST Nino 1+2
3	ANOM 3	= Anomali SST Nino 3
4	ANOM 4	= Anomali SST Nino 4
5	ANOM 3.4	= Anomali SST Nino 3.4

Data yang digunakan pada penelitian ini adalah data lag 0, lag 1, dan lag 2 pada data curah hujan dan indikator ENSO. Data lag 0 berarti data yang digunakan keduanya terjadi pada bulan yang sama. Data lag 1 artinya data curah hujan dan indikator ENSO memiliki selisih satu bulan, dengan ENSO lebih dulu terjadi. Sementara data lag 2 adalah data curah hujan dan ENSO mempunyai selisih dua bulan, data curah hujan dimulai setelah dua bulan dari terjadinya ENSO. Struktur data ditunjukkan pada Tabel 5, tanda panah untuk data (a) lag 0, (b) lag 1, dan (c) lag 2.

Tabel 5. Struktur Data Curah Hujan dan Indikator ENSO

Tahun	CH	ENSO
	Bulan ke-	
1982	1 (a)	1
	2 (b)	2
	3 (c)	3
	⋮	⋮
	11	11
	12	12

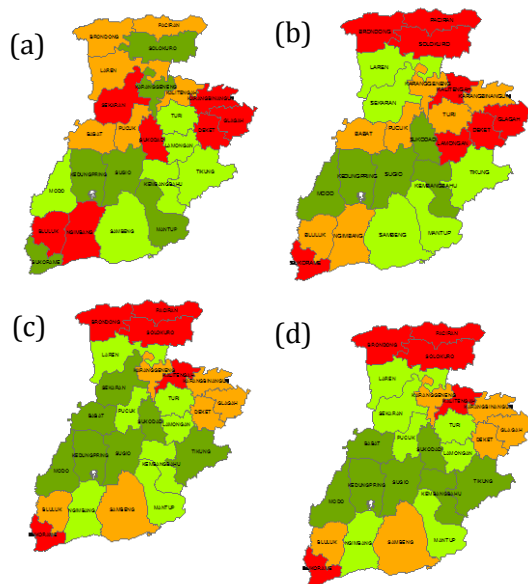
Metode Analisis Data

Metode analisis yang digunakan dalam penelitian adalah sebagai berikut.

1. Melakukan pra-pemrosesan data curah hujan.
   i). Melakukan identifikasi *missing value* dan observasi data yang tidak sesuai dari data curah hujan.
   ii). Melakukan inputasi data pada *missing value.*
   iii). Menghapus pengamatan yang tidak sesuai.
2. Melakukan identifikasi hubungan curah hujan dan indikator ENSO
   i). Membuat *scatterplot* dan histogram antara variabel *Y* (curah hujan) dan variabel *X* (ENSO).
   ii). Mendapatkan nilai korelasi Pearson, Spearman, dan Tau Kendall.
   iii). Menguji asumsi distribusi normal dengan uji *Kolmogorov-Smirnov* dan *Anderson-Darling.*
3. Melakukan identifikasi pola hubungan curah hujan dan indikator ENSO dengan pendekatan Copula.
   i). Melakukan transformasi ke domain [0,1] sebelum dilakukan analisis dependensi dengan Copula.
   ii). Membuat *scatterplot* hasil transformasi antara variabel *X* dan variabel *Y*.
   iii). Mendapatkan estimasi parameter Copula dengan pendekatan Tau Kendall.
   iv). *Fitting* Copula dan memilih Copula terbaik dengan *Maximum Likelihood Ratio.*
4. Pemilihan pola hubungan paling erat berdasarkan perbedaan *time* lag, yaitu: lag 0, lag 1, dan lag 2.
   i). Metode analisis dari tahap (2) dan (3) dilakukan pada data lag 1 dan lag 2 kedua variabel, dengan struktur data ditunjukkan pada Tabel 4.
   ii). Perbandingan berdasarkan estimasi parameter Copula dan *log likelihood* hasil analisis *time* lag.

III. HASIL DAN PEMBAHASAN

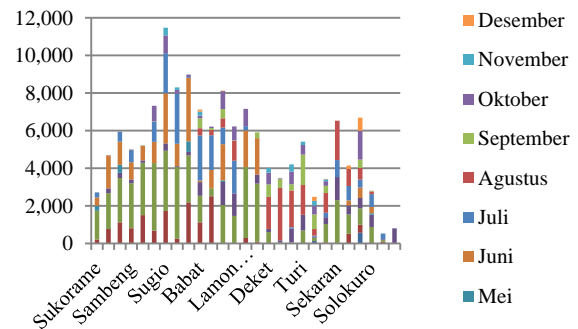
A. Karakteristik Luas Hasil Panen di Kabupaten Lamongan

Analisis karakteristik luas hasil panen di Kabupaten Lamongan digunakan untuk melihat perkembangan hasil panen setiap tahunnya di setiap kecamatan di Kabupaten Lamongan. Dari hasil analisis tersebut akan diketahui kecamatan mana yang mempunyai luas hasil terbesar dan terkecil. Jumlah

hasil luas panen di Kabupaten Lamongan disajikan pada Gambar 1.

Gambar 13. Peta Realisasi Luas Panen di Kabupaten Lamongan (a) Tahun 2010 (b) Tahun 2011 (c) Tahun 2012 (d) Tahun 2013

Gambar 1 merupakan peta penggambaran dari hasil luas panen di Kabupaten Lamongan pada tahun 2010 sampai dengan 2013 yang diambil berdasarkan peta Kabupaten Lamongan yang terdiri dari 25 Kecamatan dengan nilai interval yang didapatkan dari perhitungan nilai minimum, kuartil pertama, nilai tengah, kuartil ketiga dan nilai maksimum yang menunjukkan hasil realisasi panen di Kabupaten Lamongan pada tahun 2010 hingga tahun 2013. Dari Gambar 1 dapat dilihat bahwa terdapat dua kecamatan yang masih tergolong kategori yang sangat tinggi luas hasil panennya, yaitu 4 peta yang menunjukkan bahwa daerah dengan blok hijau tua memiliki jumlah 6955,25 Ha – 11984 Ha, yaitu Kecamatan Sugio dan Kecamatan Kedung Pring.

Berdasarkan data Sasaran Dan Realisasi Luas Panen, Produktivitas Dan Produksi Padi Dan Palawija dari tahun 2013 sampai dengan 2015 dari 27 kecamatan di Kabupaten Lamongan, diketahui bahwa luas hasil panen padi setiap bulannya adalah berbeda seperti disajikan pada Gambar 2 berikut.

Gambar 2. Kondisi Panen Padi Per Kecamatan di Kabupaten Lamongan Tahun 2013

Berdasarkan Gambar 6, pada tahun 2013, 2014, dan 2015 memiliki jumlah panen padi yang bervariasi, tetapi Bulan Maret tahun 2013 dan 2014 sama-sama memiliki jumlah panen padi terbesar, yaitu 43.975 Ha, 48.889 Ha dan 40.538 Ha, sedangkan kecamatan yang berkontribusi dalam peningkatan jumlah panen padi bulan Maret 2013 adalah Kecamatan Kedungpring, pada bulan Maret 2014 adalah Kecamatan Sugio dan Maret 2015 adalah Kecamatan Kembang Bahu. Pada bulan Juni dan Agustus di tahun 2013 yaitu sebesar 3364 Ha dan 2784 Ha. Sedangkan di tahun 2014 pada bulan Juni dan Juli juga memiliki jumlah panen yang relatif besar yaitu sebesar 3794 Ha dan 3343 Ha. Luas hasil panen terkecil yaitu 0 Ha, karena pada bulan dengan luas hasil panen 0 tidak terjadi panen pada wilayah tertentu. Pada tahun 2013 jumlah panen terbesar yaitu terjadi pada Bulan Maret, Juni dan Juli dengan besar panen adalah 43.975 Ha, 21.473 Ha dan 17.940 Ha. Pada bulan yang sama di tahun 2014 jumlah panen terbesar terjadi pada bulan Maret, Juni dan Juli sebesar 48.889 Ha, 23.781 Ha dan 17.997 Ha. Jumlah panen padi terendah pada tahun 2013 dan tahun 2014 terendah yaitu pada Bulan Desember dengan besar 1.241 Ha dan 17 Ha. Bulan panen di Kabupaten Lamongan dibagi menjadi 3 yaitu bulan Januari sampai dengan Bulan April, Bulan Mei sampai dengan Bulan Agustus dan Bulan September sampai dengan Bulan desember. Di pertiga bulan panen yang ada di Kabupaten Lamongan bulan dengan jumlah luas hasil panen terendah pada tahun 2013 adalah bulan januari, mei dan desember, dengan jumlah panen berturut-turut adalah 122 Ha, 1424 Ha dan 1241 Ha.

Berdasarkan penelitian [14] disebutkan bahwa luas hasil panen salah satunya dipengaruhi oleh curah hujan, hubungan keduanya adalah positif, dimana semakin besar intensitas curah hujan maka air yang tersedia semakin baik untuk luas hasil panen. Namun, apabila curah hujan terlalu tinggi maupun terlalu rendah yang dapat mengakibatkan terjadi banjir maupun kekeringan, dapat menyebabkan luas hasil

panen padi berkurang, keadaan seperti itu dinamakan kejadian iklim ekstrim.

Sebagai upaya *Early Warning System* terhadap masalah luas hasil panen di Kabupaten Lamongan maka diperlukan analisis untuk mengetahui hubungan antara curah hujan, indikator ENSO serta luas hasil panen di Kabupaten Lamongan.

B. Pra-Pemrosesan Data Curah Hujan

Pencatatan data curah hujan kadang terjadi perpindahan alat pengukur curah hujan, alat pengukur yang rusak, tidak tersedia tenaga pencatat, sehingga terdapat data *missing*, termasuk di stasiun pengamatan curah hujan dalam penelitian ini. Oleh karena itu diperlukan pra-pemrosesan data sebelum dilakukan analisis, yaitu meliputi identifikasi *missing value* dan inputasi data.

Tabel 6. Identifikasi Missing Value Data Curah Hujan di Kabupaten Lamongan

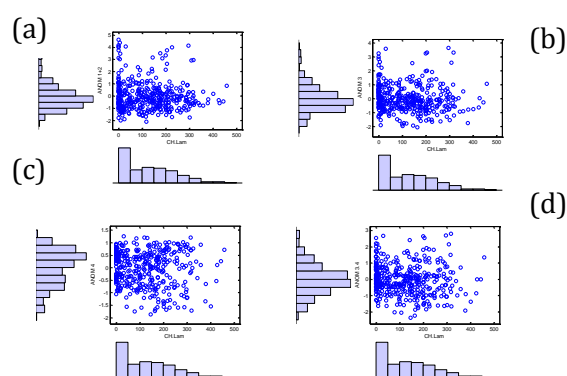
Pos Pengamatan	N tidak Sesuai	% *missing*
Karang Binangun	203	0,49
Kedungpring	203	1,38
Pangkatrejo	203	0,00
Sukodadi	203	0,56

Tabel 6 menunjukkan bahwa banyak ditemukan data *missing* di empat pos pengamatan Kabupaten Lamonngan Jawa Timur. Pos Kedungpring memiliki data *missing* paling banyak yaitu 1,38%. Pengamatan di Pangkatrejo tidak ditemukan data *missing*, namun masih terdapat beberapa pengamatan yang tidak sesuai yaitu 203 pengamatan. Jumlah data *missing* juga ditemukan sama pada pos pengamatan lain. Pengamatan tidak sesuai yang dimaksud adalah pengamatan yang dicatat pada tanggal-tanggal yang tidak mungkin terjadi, seperti tanggal 31 pada Bulan Februari, April, Juni, September, November, tanggal 30 Februari, dan tanggal 29 Februari pada tahun-tahun non-kabisat. Maka pengamatan pada tanggal-tanggal tidak sesuai dihapuskan, sedangkan untuk mengatasi *missing value* dilakukan proses inputasi data dengan mengganti data *missing* menggunakan rata-rata curah hujan pada tanggal dan bulan yang sama dengan tanggal dan bulan yang *missing* tersebut.

C. Identifikasi Hubungan Lag 0 Curah Hujan dan Indikator ENSO di Jawa Timur

Identifikasi pola hubungan antara curah hujan dan ENSO dilakukan pada data lag 0, lag 1, lag 2 curah hujan dan indikator ENSO. Curah hujan di Kabupaten Lamongan memiliki variasi yang tinggi setiap bulannya. Hal ini sering disebut sebagai iklim ekstrim yaitu sering terjadi iklim yang sangat rendah dan sangat tinggi. Gambar 5 menjelaskan kondisi curah hujan di Kabupaten Lamongan yang cenderung memiliki karakteristik curah hujan ekstrim, serta hubungan pada lag 0 curah hujan dengan indikator ENSO (SST Nino 1+2, SST Nino 3, SST Nino 4 dan SST Nino 3,4), dimana data curah hujan dan indikator ENSO yang digunakan adalah pada bulan yang sama.

Gambar 3. Scatterplot dan Histogran antara Curah Hujan di Kabupaten Lamongan dan Anomali SST: (a) Nino 1+2 (b) Nino 3 (c) Nino 4 (d) Nino 3.4

Berdasarkan histogram pada Gambar 3, curah hujan di Kabupaten Lamongan dan indiator ENSO tidak membentuk pola yang simetris. Pola distribusi data curah hujan adalah *skewness* kanan yang menunjukkan bahwa di Kabupaten Lamongan tahun 1982 – 2013 sering terjadi curah hujan dengan intensitas rendah, dengan kata lain sering terjadi musim kering atau jarang terjadi hujan.

Sementara pola distribusi anomali SST Nino 1+2, SST Nino 3, dan SST Nino 3.4 memiliki *skewness* kiri, sedangkan anomali SST Nino 4 memiliki pola distribusi *skewness* kanan. Pola hubungan anomali *skewness* kanan menunjukkan bahwa pada tahun 1982-2013 sering terjadi anomali tinggi, dengan kata lain sering terjadi El Nino, sedangkan pada anomali SST Nino 4 lebih sering terjadi La Nina karena data banyak anomali bernilai kecil.

Pola hubungan antara curah hujan di Lamongan dan indikator ENSO tidak cukup dijelaskan melalui *scatterplot* karena tidak membentuk pola yang spesifik sehingga sulit untuk menjelaskan hubungan antara kedua variabel, sehingga dilakukan analisis hubungan curah hujan dan indikator ENSO di Kabupaten Lamongan menggunakan korelasi Pearson, Spearman, dan Tau-Kendall disajikan pada Tabel 6.

Tabel 7. Koefisien Korelasi dan P-value antara Lag 0 Curah Hujan dan Indikator ENSO

Variabel		Pearson		Spearman		Tau-Kendall	
		koefisien korelasi	*p-value*	koefisien korelasi	*p-value*	koefisien korelasi	*p-value*
CH Lamongan	ANOM 1+2	-0,077	0,131	-0,079	0,118	-0,053	0,121
	ANOM 3	-0,113	**0,027**	-0,177	**0,000**	-0,121	**0,000**
	ANOM 4	-0,109	**0,032**	-0,105	**0,039**	-0,078	**0,024**
	ANOM 3,4	-0,113	**0,026**	-0,166	**0,001**	-0,116	**0,000**

Keterangan: Nilai yang di **Bold** menunjukkan signifikan pada α = 0,05

Berdasarkan pengujian korelasi yang dilakukan, dapat diketahui bahwa hubungan antara curah hujan dan indikator ENSO semuanya mempunyai hubungan negatif. Hal ini menunjukkan kejadian ENSO di Lautan Pasifik berhubungan terbalik dengan curah hujan yang terjadi di Kabupaten Lamongan, apabila di Lautan Pasifik terjadi El Nino maka di Kabupaten Lamongan terjadi penurunan curah hujan yang dapat mengakibatkan kekeringan, apabila terjadi La Nina maka di Kabupaten Lamongan terjadi peningkatan curah hujan yang dapat mengakibatkan banjir.

Pengujian distribusi normal pada data dilakukan dengan menggunakan histogram maupun secara pengujian statistik. Histogram pada curah hujan di Kabupaten Lamongan dan indikator ENSO tidak membentuk pola simetris, pola distribusi memiliki kemiringan (*skewness*). Untuk memperjelas hasil pengujian dilakukan dengan uji Kolmogorov Smirnov dan uji Anderson Darling.

Tabel 7 menunjukkan bahwa curah hujan dan indikator ENSO masing-masing memiliki *p-value* yang kurang dari α = 0,05 dan nilai D_{hitung} lebih dari $D_{0,05}$ = 0,069 ($D > D_{0,05}$), kecuali pada Anomali SST Nino 3.4. Sehingga diputuskan untuk tolak H_0 yang artinya data curah hujan di Kabupaten Lamongan, Anomali SST Nino 1+2, Anomali SST Nino 3, dan Anomali SST Nino 4 3 tidak berdistribusi Normal. Namun pada Anomali SST Nino 3.4 nilai D_{hitung} sebesar 0,058 yaitu kurang dari $D_{0,05}$ = 0,069 ($D < D_{0,05}$) sedangkan nilai *p-value* < α, oleh karena itu dengan pengujian Kolmogorov Smirnov tidak dapat disimpulkan. Sedangkan dengan uji Anderson Darling memberikan hasil *p-value* < α dan diputuskan tolak H_0 yang berarti Anomali SST Nino 3.4 tidak mengikuti distribusi normal.

Tabel 8. Uji Normalitas Lag 0 Curah Hujan dan Indikator ENSO dengan Kolmogorov Smirnov dan Anderson Darling

No	Variabel	Nilai KS(D)	*p-value*	*p-value* AD
1	CH Lamongan	0,117	<0,010	<0,005
2	ANOM 1+2	0,111	<0,010	<0,005
3	ANOM 3	0,100	<0,010	<0,005
4	ANOM 4	0,094	<0,010	<0,005
5	ANOM 3.4	0,058	<0,010	0,009

Identifikasi dengan pendekatan Copula dilakukan karena dengan analisis sebelumnya tidak dapat menjelaskan pola hubungan antar variabel. Tahap awal analisis dengan Copula adalah melakukan transformasi variabel ke domain Uniform[0,1]. Analisis dilakukan dengan pendekatan Copula Archimedean. Namun untuk Anomali SST Nino 3.4 juga menggunakan pendekatan Copula Normal.

Tabel 9 Estimasi Parameter Copula dengan Pendekatan Tau Kendall di Lamongan

Variabel		Copula	Parameter	*p-value*
CH LAMONGAN	ANOM 1+2	Frank	-0,481	0,105
		Clayton	-0,101	0,086
		Gumbel	-	-
	ANOM 3	Frank	-1,103	**0,000**
		Clayton	-0,216	**0,000**
		Gumbel	-	-
	ANOM 4	Frank	-0,702	**0,031**
		Clayton	-0,144	**0,019**
		Gumbel	-	-
	ANOM 3.4	Frank	-1,056	**0,001**
		Clayton	-0,208	**0,000**
		Gumbel	-	-
		Normal	-0,181	**0,001**

Keterangan : Nilai yang di **Bold** menunjukkan signifikan pada a=0,05

Tabel 8 menunjukkan hubungan antara curah hujan dan indikator ENSO di Lamongan mengikuti jenis Copula berdasarkan parameter yang signifikan berdasarkan pengujian *p-value*<α. Struktur dependensi curah hujan dan indokator ENSO mengikuti Copula terpilih berdasarkan parameter yang signifikan. Copula Gumbel tidak dapat diestimasi karena nilai penghitungan parameter θ <1. Seharusnya pada Copula Gumbel $\theta \in [1, \infty)$. Hal ini disebabkan karena nilai korelasi antara curah hujan dan indikator

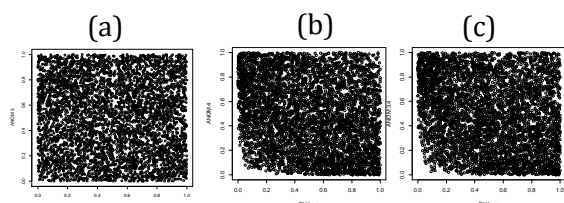
ENSO di Lamongan yang didapatkan pada penghitungan korelasi Tau-Kendall bernilai negatif (-). Struktur depedensi antara curah hujan dan indikator ENSO memiliki hubungan yang mengikuti lebih dari satu jenis Copula, karena itu untuk mendapatkan model terbaik perlu dilakukan *fitting* Copula dari struktur dependensi antar variabel. *Fitting* Copula dengan metode *Maximum Likelihood Estimation* (MLE) disajikan pada Tabel 9.

Tabel 10 Hasil Fitting Copula dengan MLE

Variabel		Copula	Estimasi	Log-likelihood
CH LAMONGAN	ANOM 3	Frank	-1,110	6,241
		Clayton	-0,180	**7,774**
	ANOM 4	Frank	-0,662	2,216
		Clayton	-0,223	**11,126**
	ANOM 3.4	Frank	-1,048	5,529
		Clayton	-0,218	**11,499**
		Normal	-0,171	5,180

Keterangan: Nilai yang di **Bold** menunjukkan signifikan pada α=0,05 dan *log- likelihood* terbesar

Model terbaik dipilih berdasarkan hasil *fitting* dengan nilai *log-likelihood* terbesar serta *p-value* signifikan pada Tabel 9. Secara visual model dependensi antara curah hujan dan indikator ENSO di Kabupaten Lamongan terpilih ditunjukkan melalui *scatterplot* rank Copula seperti pada Gambar 4.

(a) (b) (c)

Gambar 4. Scatterplot Rank Copula Bangkitan Data (n=5000) antara Curah Hujan di Lamongani dengan: (a) Anomali SST Nino 3, (b) Anomali SST Nino 4, (c) Anomali SST Nino 3.4

Gambar 4 menunjukkan dependensi antara curah hujan dan indikator ENSO di Kabupaten Lamongan. Model dependensi antara curah hujan di Lamongan dan Anomali SST Nino 3, Anomali SST Nino 4, SST Nino 3.4 masing-masing mengikuti Copula Clayton. Copula Clayton memiliki *tail* dependensi di bawah. Hal ini menunjukkan ekstrim terjadi ketika curah hujan di Lamongan dan Anomali SST Nino 3, Anomali SST Nino 4, SST Nino 3.4 nilainya rendah. Semakin rendah Anomali SST Nino 3, Anomali SST Nino 4, SST Nino 3.4, dan curah hujan maka hubungan semakin erat. Artinya jika anomali turun, maka curah hujan di Kabupaten Lamongan akan mengalami penurunan juga.

Melalui cara yang sama didapatkan model dependensi antara curah hujan dan indikator ENSO pada lag 1 dan lag 2, yang ditunjukkan pada Tabel 8. Hasil identifikasi struktur dependensi antara curah hujan dan indikator ENSO menunjukkan adanya hubungan di Kabupaten Lamongan dengan mengikuti Copula Frank dan Clayton. Namun antara curah hujan dan Anomali SST Nino 1+2 di Kabupaten Lamongan menunjukkan tidak adanya hubungan yang erat antara keduanya.

Tabel 11 Perbandingan Parameter Copula pada Lag 0, Lag 1, dan Lag 2

CH Lamongan	ANOM 1+2	ANOM 3		ANOM 4		ANOM 3.4	
		Estimasi	Log-likelihood	Estimasi	Log-likelihood	Estimasi	Log-likelihood
Lag 0	-	-0,180[B]	**7,774**	-0,223[B]	**11,126**	-0,218[B]	**11,499**
Lag 1	-	-1,135[A]	**6,418**	-0,233[B]	**11,863**	-0,203[B]	**12,104**
Lag 2	-	-0,971[A]	**4,703**	-	-	-0,187[B]	**10,387**

Keterangan: A = Mengikuti Copula Frank (Tidak Memiliki Tail Dependensi)
B = Mengikuti Copula Clayton (Tail Dependensi di Bawah)
\- = Tidak Mengikuti Copula

Identifikasi pola hubungan curah hujan dengan perbedaan *time* lag menunjukkan adanya perbedaan parameter Copula dan nilai *log-likehood*. Pemilihan hubungan keeratan curah hujan dan indikator ENSO dapat dilihat berdasarkan estimasi parameter Copula dan nilai *log-likelihood* yang ditunjukkan pada Tabel 8. Semakin besar nilai estimasi parameter yang dihasilkan, semakin erat hubungan keduanya. Serta semakin besar nilai *log-likelihood*, maka semakin besar keragaman yang dapat dijelaskan pada hubungan keduanya, dengan kata lain hubungan keduanya semakin jelas. Selain itu, dapat dilihat berdasarkan hasil visualisasi bentuk *rank* Copula terpilih. Semakin jelas bentuk *rank* Copula, semakin erat hubungan keduanya.

Hasil estimasi parameter pada lag 0, lag 1, dan lag 2 antara curah hujan dan indikator ENSO menghasilkan nilai parameter yang negatif. Hal ini menunjukkan hubungan keduanya adalah terbalik, dengan kata lain apabila terjadi El Nino di Lautan Pasifik maka curah hujan di Kabupaten Lamongan akan mengalami penurunan bahkan dapat mengakibatkan terjadinya kekeringan, dan sebaliknya

apabila terjadi La Nina maka curah hujan akan meningkat dan dapat mengakibatkan terjadinya banjir Tabel 8 menunjukkan bahwa hubungan paling erat berdasarkan *time lag* adalah terjadi saat lag 1. Hal ini berarti bahwa kejadian ENSO di Lautan Pasifik akan mempengaruhi curah hujan satu bulan berikutnya. Selain itu rank Copula antara lag 1 curah hujan dan indikator ENSO lebih jelas bentuknya daripada rank Copula yang lain. Serta dapat disimpulkan Anomali SST Nino 3.4 adalah anomali yang paling tepat digunakan dalam mengidentifikasi hubungan curah hujan dan indikator ENSO, yaitu pada lag 1 karena memiliki nilai *log-likelihood* terbesar.

Seperti yang telah disimpulkan sebelumnya bahwa indikator ENSO mempunyai hubungan negatif satu bulan berikutnya terhadap curah hujan di Kabupaten Lamongan, serta indikator ENSO yang paling tepat digunakan adalah Anomali SST Nino 3.4. Sehingga dapat disimpulkan bahwa terdapat hubungan antara luas hasil panen per bulan dengan Anomali SST Nino 3.4. Dimana kejadian ENSO mempengaruhi satu bulan berikutnya terhadap luas hasil panen di Kabupaten Lamongan.

Berdasarkan Gambar 6 diketahui bahwa pada Bulan Maret 2013 menghasilkan panen yang terbesar, dimana pada Bulan Februari 2012 terjadi anomali normal, sedangkan pada Bulan Desember 2014 dan Januari 2015 luas hasil panen sangat kecil, hal ini dikarenakan pada Bulan November dan Desember 2014 terjadi kejadian ekstrim yaitu El Nino di Lautan Pasifik, sehingga terjadi kekeringan dan menyebabkan luas hasil panen yang sangat kecil.

Melalui penjelasan sebelumnya dapat diperoleh suatu metode untuk *early warning system* dimana satu bulan berikutnya Anomali SST Nino 3.4 yang terjadi berpengaruh terhadap curah hujan serta luas hasil panen padi di Kabupaten Lamongan. Sehingga dapat diketahui melalui Anomali SST Nino 3.4 pada Bulan Juni 2015 akan terjadi penurunan luas hasil panen karena pada Bulan Mei terjadi El Nino di Lautan Pasifik.

Dari hasil yang dicapai pada bab 4 diketahui curah hujan yang terjadi di Kabupaten Lamongan dipengaruhi oleh indikator ENSO. Keduanya mempunyai hubungan negatif dengan indikator ENSO yang paling tepat digunakan adalah Anomali SST Nino 3.4. Dimana kejadian ENSO mempengaruhi satu bulan berikutnya terhadap curah hujan serta luas hasil panen di Kabupaten Lamongan.

Potensi hasil yang diharapkan dari penelitian ini adalah mengurangi luas gagal panen di Kabupaten Lamongan Jawa Timur akibat iklim ekstrim curah hujan. Analisis melalui indikator ENSO dapat digunakan untuk mengetahui curah hujan serta luas hasil panen yang akan terjadi satu bulan berikutnya di Kabupaten Lamongan. Sehingga dapat dilakukan upaya dalam mencegah terjadinya penurunan luas hasil panen padi khususnya di Kabupaten Lamongan Jawa Timur. Seperti penelitian yang dilakukan oleh [15] yang menggunakan data El Nino Southern Oscillation Climate untuk memprediksi produksi padi di indonesia menunjukkan bahwa prediksi kuantitatif efek ENSO pada panen padi dapat memberikan alat tambahan untuk mengelola ketahanan pangan.

VI. KESIMPULAN DAN SARAN

Hasil analisis dan pembahasan pada penelitian ini didapatkan kesimpulan sebagai berikut.

1. Berdasarkan analisis karakteristik data luas panen pada di Kabupaten Lamongan tahun 2010-2013 diketahui bahwa kecamatan Solokuro dan kecamatan Sukorame mengalami penurunan hasil panen yang sangat drastis pada tahun 2010 ke 2011 dan seterusnya. Diketahui dari data bulanan bahwa bulan Maret tahun 2013 sampai dengan 2015 dan bulan Juni dan Juli tahun 2013 dan 2014 memiliki jumlah luas hasil panen terluas. Sedangkan pada bulan Desember tahun 2013 dan 2014 memiliki hasil panen yang sangat rendah bila dibandingkan dengan bulan lainnya.
2. Hubungan paling erat antara curah hujan di Kabupaten Lamongan dan indikator ENSO terjadi pada selisih 1 bulan, kejadian ENSO akan mempengaruhi curah hujan di Kabupaten Lamongan satu bulan berikutnya. Hal ini terjadi karena kemungkinan adanya faktor lain yang mempengaruhi hubungan curah hujan di Kabupaten Lamongan dan kejadian ENSO di Lautan Pasofik. Indikator ENSO yang paling tepat adalah Anomali SST Nino 3.4 untuk digunakan dalam mengidentifikasi hubungan curah hujan dan indikator ENSO.
3. Pola hubungan antara curah hujan dan indikator ENSO dengan perbedaan *time* lag sebagai Early Warning System di Lamongan, Jawa Timur dengan Anomali SST Nino 3.4, maka pada Bulan Juni 2015 akan terjadi penurunan luas hasil panen karena telah diketahui pada bulan Mei 2015 terjadi El Nino di Lautan Pasifik.

Saran yang dapat diberikan berdasarkan penelitian ini adalah sebagai berikut.

1. Pengaruh indikator ENSO terhadap curah hujan di Kabupaten Lamongan kemungkinan dipengaruhi juga oleh faktor lain. Penelitian selanjutnya disarankan untuk memperhatikan faktor lain yang kemungkinan dapat mempengaruhi hubungan curah hujan dan indikator ENSO, dikarenakan antara Lautan Pasifik dan Kabupaten Lamongan memiliki jarak yang jauh.
2. Salah satu faktor yang mempengaruhi luas hasil panen adalah curah hujan, namun perlu

diperhatikan faktor lain yang dapat berpengaruh salah satunya adalah faktor lokasi seperti dataran tinggi pegunungan, dekat pantai, dan lainnya.

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"Upaya mitigasi dan adaptasi perubahan iklim, khususnya di Indonesia memerlukan pendekatan sains dan teknologi yang berbeda dengan negara lain pada umumnya. Hal ini mengingat posisi geografis dan juga karakteristik negara kepulauan yang dimiliki Indonesia. Inilah yang menjadi alasan mengapa kita harus memiliki roadmap penelitian yang fokus untuk memastikan bahwa informasi sains dan teknologi yang diterapkan sesuai dengan kondisi kewilayahan yang ada, sesuai yang disajikan dengan buku ini"

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